

The AMSAT[®] Journal

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CONTENTS

UNAMSAT/TECHSAT Fail to

Achieve Orbit 1

Apogee View 3

By Bill Tynan, W3XO

Phase 3D, A New Era for Amateur
Satellites 5

By The Phase 3D Design Team

Current Amateur Satellite
Frequencies 16

Launch Opportunities Beyond
Phase 3D 17

By Philip Chien, KC4YER

Satellite Orbital Elements 17

By Ray Hoad, WA5QGD

The Four Seasons of AO-13 23

By William Roth, N7RYW

1995 AMSAT Field Day Competition
Announcement 27

Digital Communications with
Phase 3D 29

By Harold Price, NK6K

UNAMSAT/TECHSAT Fail to Achieve Orbit

Two amateur satellites were lost when their launch vehicle failed to achieve orbit. The Mexican satellite UNAMSAT and the Israeli-built Gurwin-1 TECHSAT were part of the payload of a Russian SS-25 rocket, which was launched from Russia's Plesetsk Cosmodrome on March 28. According to David Lieberman, XE1TU, the failure was caused by the failure of the third stage to burn completely. As a result the fourth stage ignited too early, before the separation of the third and fourth stages. As a result, the launcher blew up.

In November, 1193 the first test launch of a converted SS-25 (originally designed for use as an ICBM launch vehicle) was successful, but with a lighter payload. It had been hoped that the Russian rockets would provide an inexpensive way to launch amateur radio satellites.

Both satellites were designed for packet radio use. Gurwin-1 TECHSAT was built at the Technion-Israel Institute of Technology in Haifa as a 9600 bit/s store and forward satellite. UNAMSAT was assembled by students at the Universidad Nacional Autonoma de Mexico (UNAM) in Mexico City. In addition to packet store and forward operation at 1200 bits/s UNAMSAT carried a unique "meteor radar" experiment.

Early reports indicated that TECHSAT and UNAMSAT were to have been accompanied on the flight by two Russian satellites. A later report from AMSAT-UK indicated that there was indeed a third payload, but that it was simply a dummy.

Reports from the Israeli and Mexican project sponsors indicate that both satellites will be reconstructed. A "spare" version of UNAMSAT does exist and an effort will be made to find an alternative launch.

AMSAT-NA President Bill Tynan expressed deep sorrow over this substantial loss to all of those who worked so hard to design and construct these spacecraft and to the entire amateur satellite community worldwide.

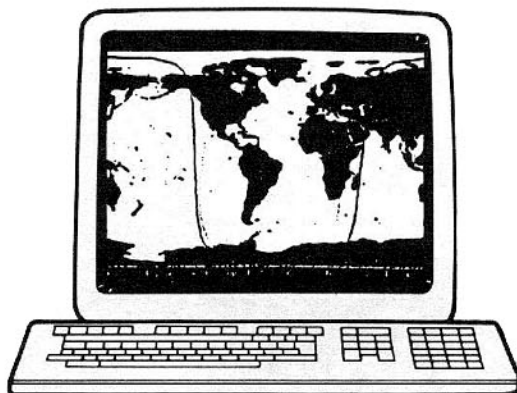
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Apogee View

The Year of Decision

by Bill Tynan W3XO

As I write this, there is just one year to the scheduled launch of Phase 3D on the second flight test of Ariane 5. The first flight test, Ariane 501, is set for next November. So, by then, we will know a lot more of how that launch vehicle development program, so important to us, is going.

One year is not much time in the building of a spacecraft the size and complexity of Phase 3D, especially by a relatively small group of mostly volunteers. But, all of those involved in the construction of Phase 3D are determined to successfully complete the project.

As of the end of March, the spaceframe is complete and at the Phase 3D Integration Facility in Orlando, Florida; as it has been since last summer. The propellant tanks have arrived from Russia. The plumbing system for the liquid fuel motor has been fabricated by Dick Daniels W4PUJ and will be installed by the time you read this. Dick Jansson WD4FAB reports that the SBS, the structure in which Phase 3D will ride into space, is in its final stages of construction at Weber State University in Utah. He also advises me that the panels on which the solar cells will be mounted are complete and await only application of a special paint before being shipped to Germany where the cells will be applied.

Good progress is being made on the electronic modules. Mike Dorsett G6GEJ has the 2 meter transmitter essentially complete and most of the receiver modules, being built in several European countries, are about ready to go as well. The other units coming from Europe are in their final stages of construction and checkout. A prototype of the flight computer has been completed for some months and has been undergoing evaluation by Peter Guelzow DB2OS. This has lead to a few needed changes which are now being cranked in by Lyle Johnson WA7GXD and his crew. They expect to have the flight unit finished in about 30 days. Similar progress is being made on the other

computers Lyle's group is constructing - one for the RUDAK and the other dedicated to the GPS Experiment.

The spacecraft wiring harness is now well underway thanks to the persistent work of Mike Garrity N4OZC, who has been putting in long hours at the Integration Facility. Also newly arrived to help Stand Wood WA4NFY with construction and test of flight antennas, is Jeff Zerr, who although not a licensed ham, was instrumental in the MICROSAT Project. Another new arrival at the facility is a person many will recognize from SAREX. He is Lou McFadin W5DID who has just retired from the Johnson Space Center in Houston and will be working full time on all aspects of getting Phase 3D ready to fly. While packing, Lou found time to wind the magna-torque rods which are an important component of the satellite's attitude control system.

The major article in this issue of the AMSAT Journal should provide a lot more information about Phase 3D and what it will do for all of Amateur Radio.

By the time this issue of the Journal arrives in your mailbox, you have probably already seen the May issue of QST with Phase 3D featured on the cover. The issue also contains a major article on the satellite by Steve Ford WB8IMY. It also announces a new fundraising campaign being mounted by the League, as approved at their January Board meeting.

Speaking of fundraising, a report on that aspect of the project is in order. ARRL's earlier campaign netted almost \$200,000, all of which will be used to support the launch fee that must be paid to the European Space Agency. Of course this is only a small part of the amount needed. The rest will come from funds raised in Europe, which are substantial. Although not coming close to matching what the Europeans have been able to raise, AMSAT-NA's own campaign has been quite successful, with some \$400,000 taken in so far. Up to this point, our members have come through very well indeed. The disappointment has been that, despite

a number of attempts, we have been totally unsuccessful in attracting any donations from corporations or foundations. Nevertheless, if our campaign continues on track, the new ARRL effort is as successful as it is expected to be, and the substantial sum the Europeans have managed to amass; it appears that there are sufficient funds to complete and launch Phase 3D. The words "continues on track", are very important, as considerable expenses are certain to be encountered over the next year to complete and test the satellite. Whether or not there will be enough to be able to purchase launch insurance, depends on how much remains after the paying all of these bills.

So, this is no time for any of us to conclude that we have "done enough". Please respond as generosity as you can to the ARRL campaign and continue your pledge payments to the AMSAT-NA Phase 3D fund. If you haven't yet pledged, or made a contribution, that can be arranged easily. Just drop a note to

AMSAT PO Box 27 Washington, DC 20044, or call 301-589-6062.

With all of us doing all we can, Phase 3D should be in orbit by this time next year!

On a sadder note, I want to express our collective sorrow to all of those who worked so hard on the UNAMSAT-1 Project in Mexico and the TECHSAT-1 Project in Israel. We were all looking forward to using those two satellites and are

very disappointed at their loss. However, we know that our disappointment doesn't come close to that of those who toiled long and hard to complete these two spacecraft. We know how they feel as we had an identical kind of loss when the vehicle on which Phase 3A was riding fell into the sea soon after lift-off fifteen years ago. Unfortunately, losses like these are one of the risks we all face in launching satellites. As difficult as it is, we all must bounce back from them, and begin anew.



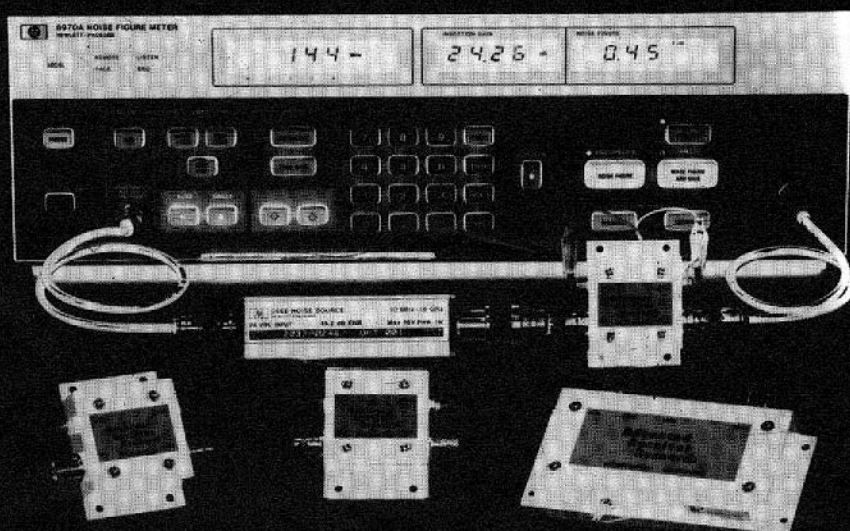
Call for Papers

The 1995 AMSAT Annual Meeting and Space Symposium to be held in Orlando, Florida this October is currently accepting papers to be presented at the meetings. Summaries are requested by July 1, photocopy ready papers by August 12th. If you are interested in presenting, please contact:

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SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
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Phase 3D, A NEW ERA FOR AMATEUR SATELLITES

by
The Phase 3D Design Team

Successful use of amateur satellites, OSCARs 10 AND 13 require a single multi-mode VHF/UHF rig delivering 50 to 100 Watts (or at least a 2 meter receiver and a 70cm transmitter) and two directional antennas (one for 2 meters and one for 70cm) that can be aimed in both azimuth and elevation. Phase 3D, currently under construction, is aimed at significantly simplifying these requirements plus adding many other modes of operation i.e. frequency choices. A number of specific design features are being incorporated into Phase 3D to make it much more accessible to amateurs throughout the world, as well as more flexible for the years to come. However, in addition to substantially reducing the ground station requirements, Phase 3D is being specifically designed to assist the continued march of Amateur Radio toward ever higher frequencies - begun in the early 1920s at 200 meters. This is important, if amateurs are to retain the use of these bands; which, in the next century, may turn out to be some of the most valuable assignments we have. As commercial and government communicators have already discovered, satellites can make these upper reaches of the spectrum very useful for communication between widely scattered points on the Earth. In addition, the time may not be too far off when we are using the GHz bands to talk to hams on space stations, the moon and planets. Phase 3D will give us the incentive we need to begin making more use of these valuable assignments.

A Truly International Project

Phase 3D is truly international in scope. Not only is it being aimed at bringing satellite operation to within the reach of virtually every licensed amateur in the world, but it is being designed and built by an international team comprising people from some dozen countries. Much of the early conceptual work was done in Germany. Three of the transmitters, which will be aboard, are being built in that country. The 10 meter bulletin transmitter is a product of the South African AMSAT group. The 2 meter transmitter is being designed and built in the U.K. A group in Finland is supplying the 10 GHz transmitter and its associated antenna. The 24 GHz transmitter, along with its antenna, is coming from Belgium. The IF matrix and LEILA (more on it later) is of German design. Receivers are being supplied by groups in Belgium, Germany, Slovenia and the Czech Republic. The propellant tanks came from Russia. What promises to be a very interesting camera experiment is the product of the Japanese JAMSAT group. All of the spacecraft's antennas, with the exception of those associated with the 10 GHz and 24 GHz transmitters, are being developed by a U.S. team. A group in Hungary is supplying the Battery Charge Regulator and a communications experiment. Construction of the spaceframe and the launch vehicle adaptor are taking place in the U.S. where much of the mechanical and thermal design work took place.

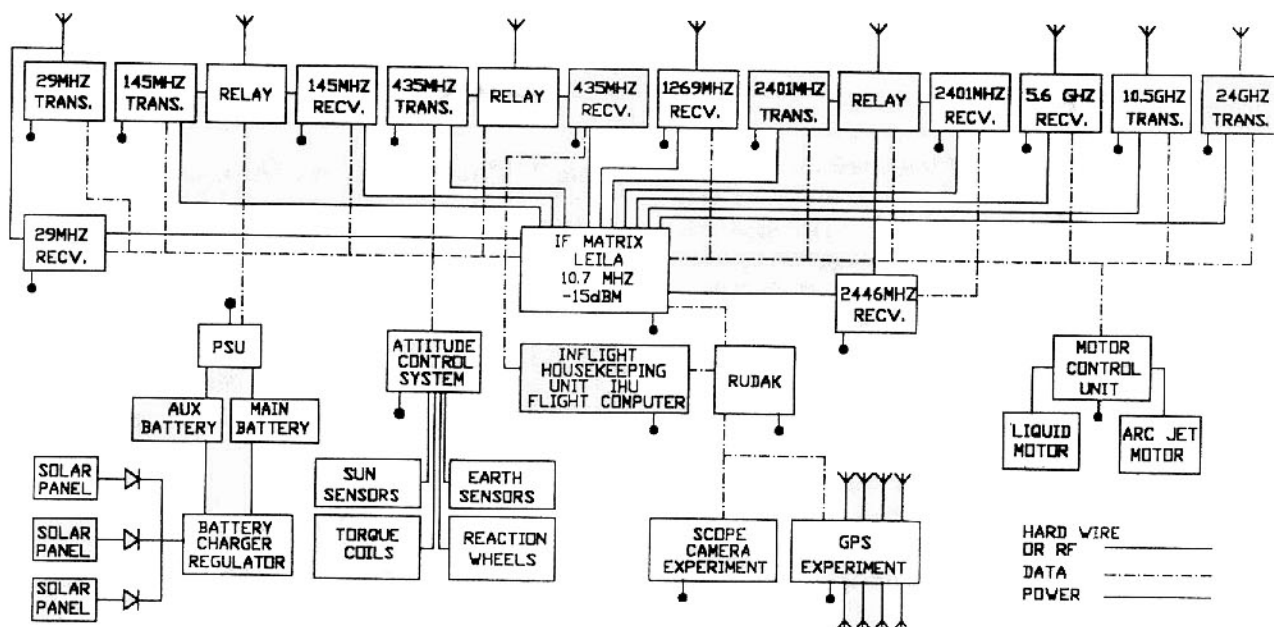


Figure 1

Phase 3D Block Diagram

Other contributions to the Phase 3D project, from this part of the world, include the design and construction of the GPS subsystem, the latter with some help from Canada. Much of the basic design for the main spacecraft computer, the IHU, came from Germany; but it is being built by a U.S. team with German and British help. In addition, this same group, is also undertaking the design and construction of two other Phase 3D computers. One of these is called RUDAK and the other is a dedicated computer for the GPS experiment. The Arc-jet motor is currently under development by a group at the Institute for Space Systems at the University of Stuttgart in Germany. Radiation testing of various solid state components has been taking place in Canada.

Assembly and check-out of the spacecraft is taking place at a facility set up in Orlando Florida. Launch, aboard the second test flight of the European Space Agency's new heavy lift Ariane 5 vehicle in April 1996, will be from ESA's launch complex at Kourou, French Guiana in South America.

A New Approach

Previous amateur satellites have utilized transponders. A transponder can be characterized as a single box which receives signals on one band of frequencies and puts out an amplified replica of these same signals on another band of frequencies. Instead of dedicated transponders, which limit flexibility, Phase 3D will employ the approach shown in Figure 1. The satellite's communication package will consist of a series of receiver front-ends and transmitter mixer/power amplifiers linked by a common IF. The outputs of any of the receiver front-ends can be connected to the IF Matrix, which in turn can be connected to any of the mixer/power amplifiers - all under computer control. This means that uplinks and downlinks can be set up on any of the bands for which hardware exists on the satellite. This is very important, because no one can say for sure what bands will be most viable for uplinks and downlinks in, for example, 2005 - the year that Phase 3D (OSCAR ?) will be nine years old, and expected to be still going strong. By configuring the satellite in this manner, a variety of circumstances can be accommodated by software loaded from the ground. Fig 2 illustrates the expected arrangement of uplink and downlink frequencies.

Because of this flexibility to interconnect various receivers with various transmitters; the old "Mode" designations, which amateur satellites have used for years, has become obsolete. As a result, a new system of designations will be put into use with the launch of Phase 3D. This calls for separate letters designating the various uplink and downlink bands. Each uplink/downlink configuration will employ one or more letters depending on what uplink(s) and downlink(s) are activated. The uplink(s) will come first, followed by the downlink(s), separated by a "/". The various bands, currently planned for Phase 3D, will be designated as shown in Table 1.

Thus, what we currently call "Mode B" will become "Configuration U/V". No doubt, in use this will be shortened to "Config. U/V". Because of the flexibility offered by the matrix, combinations such as "Config. UL/VSX" are possible. (Satellite tracking software writers please take note.) Naturally, combinations such as U/U or V/V are not possible because transmitters and receivers cannot be operated simultaneously on the same band.

Figure 2 illustrates the flexibility afforded by this new approach.

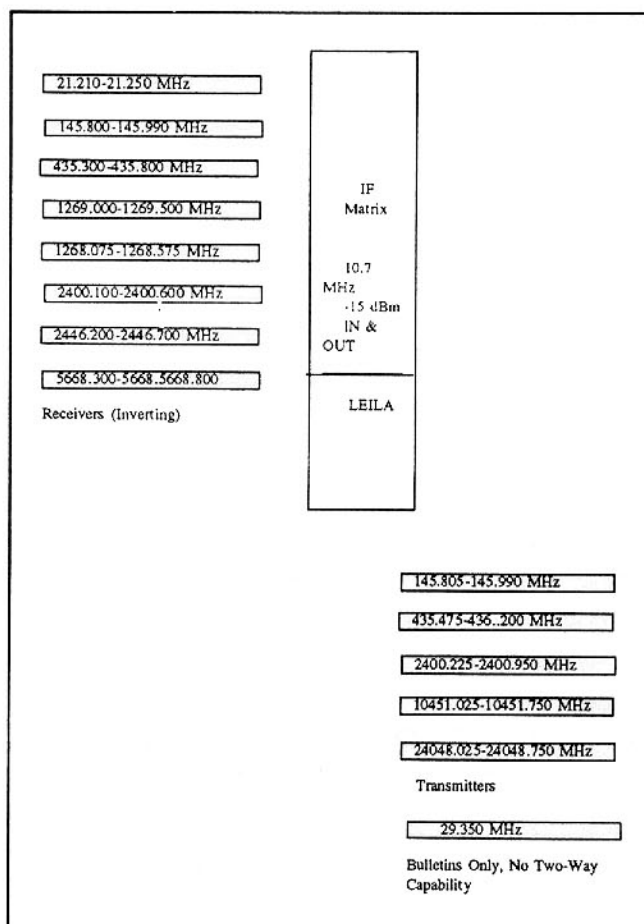


Figure 2
Phase 3D Transmitter/Receiver Matrix

Table 1 Phase 3D Band Designations.

Band	Uplink	Downlink
15m (21 MHz)	H	None
10m (29 MHz)*	None	T
2m (146 MHz)	V	V
70cm (435 MHz)	U	U
23cm (1260 MHz)	L	None
13cm (2.4 GHz)	S	S
5cm (5.6 GHz)	C	None
3cm (10 GHz)	None	X
1.25cm (24 GHz)	None	K

* The 10 meter transmitter is for furnishing bulletins and similar information only, and is not configured to support two-way communications.

Overall Design Considerations

Four specific design features are being incorporated into Phase 3D to provide this greater ease of use and to increase its flexibility. First, the transmitters will have significantly higher output powers. Second, the antennas on Phase 3D will have higher gain than their cousins on AO-10 and AO-13. Third, the antennas on Phase 3D will always point toward Earth. Both OSCARs 10 and 13 were designed to be spin stabilized in inertial space. Thus, for one part of the orbit, the "high" gain antennas might be oriented toward Earth. However, for the rest of the orbit, they are pointed out into space. In order to provide some operation during this time, both satellites include low gain antennas. Not surprisingly, the "high" gain antennas are used near apogee and the low gain antennas near perigee. But there are lots of times when neither set of antennas is optimum. Of course, since the failure of OSCAR 10's flight computer, it has not been possible to orient it, so its low gain antennas are used at all times. Table 2 shows how Phase 3D will stack up with OSCAR 13 when that satellite is using its "high" gain antennas.

Table 2 Comparison of Transmitter PEP and Antenna Gain for Phase 3D and OSCAR-13

Downlink	AO-13			P 3D			P-3D Adv.	
	Xmtr pwr	Ant gain	EIRP	Xmtr pwr	Ant gain	EIRP		
	W	dB	W	W	dB	W	dB	
2m	50	5.5	180	130	11	1,700	9.7	
70cm	50*	9.5	300	250	15.3	8,471	14.5	
13cm	1	9.0	8	50	19.5	4,456	27.4	
3cm	--	--	--	50	20	5,000	--	
1.25cm	--	--	--	1	20	100	--	

* This transmitter is no longer functioning.

Keeping Phase 3D always oriented toward Earth is a major undertaking in itself. Just meeting this one objective, adds considerable complication to the spacecraft's design. First, the satellite must "know" its orientation with respect to space and then calculate its orientation with respect to Earth - depending on its location in the orbit. To determine its spatial orientation, two approaches are being taken. The primary one employs sun, and Earth sensors. A secondary, experimental system involves the use of signals from the GPS satellites. This makes use of the phase difference between GPS signals arriving at different points on the spacecraft. However, merely determining the orientation of the satellite is only part of the problem. Once this is known, it is necessary to do something to correct for the continual misorientation caused by the satellite traversing its orbit as well as smaller drifts that build up over time. The way most of the big geostationary TV satellites do it is to use gas jets to keep the satellite in the right attitude as well as in the right orbit. When their stored gas is used up, their useful life is over. In fact, depletion of their stored gas is the principal cause of the demise of geostationary satellites. In addition, most big TV satellites spin. This is done primarily to keep one side from becoming too hot and the other too cold. Their antennas are mounted on platforms which are driven by motors which turn at the same speed as the satellite's spin, but in the opposite direction. In this

way their antennas are always aimed toward Earth. In order to obtain as long a life as possible for Phase 3D, it was decided early-on that some means, other than stored gas, had to be used to provide continuous orientation of the satellite. The method adopted employs a set of spinning wheels. The momentum, associated with the spin of these wheels, reacts to reorient the satellite. Proper operation of this system is essential if Phase 3D is to meet its main objective of bringing satellite operation to many more hams on the ground.

Attitude Control Subsystem

As stated above, Phase 3D differs from previous OSCARs in that it can maintain any desired pointing angle (attitude). This is accomplished through the use of a complex attitude control subsystem. During normal operation, the pointing angle will be adjusted continuously throughout the orbit to cause the antennas on the top of the spacecraft to point towards the center of the Earth. The other degree of freedom (rotation of the spacecraft about the antenna boresight axes) will be used to maximize the amount of sunlight illuminating the solar panels.

All pointing operations are continuously operated by the main onboard computer, the IHU or Integrated Housekeeping Unit. During the times of motor firing, the computer will direct orientation of the spacecraft such that the motor thrust points into the correct direction. The mathematical calculations to compute the necessary angles are quite involved. Fortunately, because these same kind of computations were also needed for OSCARs 10 and 13, the necessary programming already exists. Thus, it is planned to draw heavily on this existing software,

The attitude Control Subsystem hardware consists of; a set of three magnetically suspended, orthogonally mounted reaction wheels, a complement of Earth and Sun sensors and associated electronics, two rings of electromagnets, the field of which can be stepped through six directions, six nutation dampers and the Inflight Housekeeping Unit (computer).

All five of these components are necessary to achieve successful attitude control. Basically the three reaction wheels store the momentum to provide the spacecraft with some intrinsic attitude stiffness, like any gyro system - or, a spinning spacecraft. But because the momentum now is in the wheels, the spacecraft itself can remain at a fixed attitude.

Because there are three wheels, mounted 90° to each other, it is possible to redistribute momentum between the wheels by simply controlling the individual speed of each. Since the initial momentum of the spacecraft is conserved, and thus fixed in space, the only way a redistribution of momentum can take place is by the spacecraft itself changing its attitude. As previously stated, these wheels employ magnetic bearings, thus eliminating the problems inherent with lubricants in space, or the frictional wear which might occur with conventional bearings over the expected 10 to 15 year life of the spacecraft.

The reaction wheels are a joint project of the University of

Darmstadt, and the University of Marburg in Germany and are nearly complete and ready for test. Each wheel is expected to consume about 5 W of power for a total 15 W.

In order to effect the attitude control, the IHU computer requires data on the current actual attitude of the spacecraft with respect to inertial space. The aforementioned Sun and Earth sensors will be used as primary references to obtain this information. As stated earlier, it is also planned to be able to employ information from the GPS subsystem to determine spacecraft attitude.

It is unavoidable that solar radiation pressure exerts a small, but finite, force on any spacecraft. It would be very unusual, and fortuitous, if this force were to pass through the center of gravity of the spacecraft. Thus, this misalignment of radiation pressure causes some small amount of torque to act on the satellite. This "nuisance" torque must be compensated for in some way or the wheels would have to be driven at an ever increasing speed. This eventually would lead to disaster, unless some means is provided to get rid of this accumulated torque. In Phase 3D, this "momentum dumping" will be achieved against the Earth's magnetic field with the two ring electromagnets.

Their operation is similar to the magnetic torquers in AO-10 and AO-13. Of course the IHU computer needs a strategy to regularly dump momentum by this system. The algorithms are not very much different from those of the above mentioned satellites. Additionally, since Phase 3D will be spin stabilized during its early life in orbit, including its first motor burns, it, like AO-10 and AO-13, will have the need for nutation dampers. The units to be used on Phase 3D are residual hardware from these earlier projects. Another example of "if it ain't broke, don't fix it!"

This magnetic torquing system consists of two hexagonal rings of magnets with a total of 12 wound rods. The two magnet rods on each side are in series, with a parallel connection to the two rods on the opposite side. This allows for a total of three magnet combinations, each one of which is switched to send current in either of two directions by the IHU. Thus, six possible polar conditions are available. As the rods are computer controlled, they can be quickly switched to take care of spinning conditions. Their total power dissipation is about 10.7 W. The rods are operated at about 1.2 Tesla flux (12,000 Gauss).

These torque rods and their associated hardware are complete and awaiting installation into the spacecraft.

The Phase 3D attitude control system will be described more fully in a future paper. But from this description, it should be clear that quite a sophisticated system is necessary to maintain optimum antenna pointing for the Amateur Radio payloads as well as to achieve a high level of power generation by the solar arrays.

Thermal Control Subsystem

Three axis stabilization carries with it another consideration. As

stated earlier, the TV-sats spin in order to keep any side from getting too hot and the opposite side too cold. As noted earlier, once in its desired orbit and orientation, Phase 3D will not spin, but will be oriented in three-dimensional space, with the antennas continually facing Earth. This continual attitude adjustment, with one side facing the sun, causes some interesting thermal design problems. The Phase 3D solution to overcome most of these problems is through the use of the four heat pipes. A heat pipe is a thermal linkage of very high conductivity consisting of a closed, evacuated tubular chamber with walls lined with a wick and partially filled with a pure fluid. The fluid used in Phase 3D is anhydrous ammonia. The fluid is vaporized at the hot end. The vapors then move through the hollow core of the tube, and condense at the cold end; from which the resulting liquid is returned through the wick to the hot end by capillary action. By this process, heat is transported from the hot to the cold end. Heat pipes typically offer heat transport characteristics that are many times greater than the heat transfer capability of the best heat conducting materials, while maintaining an essentially uniform temperature. The process requires no power and operates satisfactorily in a zero-gravity environment.

In the case of the Phase 3D spacecraft, the internal ring-shaped heat pipes can be likened to a meat-cooking rotisserie, removing heat from one part of the spacecraft and re-distributing the energy to other parts where it is ultimately transported through the sides of the spacecraft and thence radiated to space - the ultimate "heat sink". What is felt to be a unique feature of this heat pipe system, as employed on Phase 3D, is that none of the pipes come in direct contact with space-facing panels. Instead they depend upon indirect re-radiation of the heat from internal equipment mounting panels to side panels that are deliberately allowed to become cold. All along, however, the electronic equipment modules maintain their desired temperatures because of the thermal influence of the heat pipe system, regardless of whether those modules are mounted on the solar heated side, or on the space-cold backside of the spacecraft.

The earlier Phase 3A, B and C satellites employed several multi-layer thermal insulation blankets to assist these spacecraft through the thermal rigors of spaceflight. Quite simply, such blankets are a first-class nuisance to fabricate, as the required assembly technology is very exacting. In the case of Phase 3D, the side panels of the spacecraft will be painted black to provide heat rejection. The top and bottom panels will be mostly solar energy absorbing metallic finishes of several different types, depending upon the location and desired temperatures of that section of the spacecraft. In general, the thermal design calls for the mean spacecraft temperatures to be between -5 and +20° C for the expected range of sun angles (β) from -80° to +80°.

Extensive computer thermal analyses of the Phase 3D spacecraft have given us a very comfortable confidence that this design will provide the desired results, without the use of the kind of thermal blankets used on most other satellites including AO-10 and 13. These thermal analytic computations were accomplished on a home computer of the 80486-DX2/66 class; a process that required crunching through numbers for 10 to 13 hours (3 hours

once a Pentium 90 was on line) at a time to produce a series of temperature performance curves.

More Power Needed

As stated, one of the design features intended to make Phase 3D more accessible to smaller ground stations will be the use of higher power transmitters. This increased power carries with it another set of problems. First, the power must be generated. This means more solar array area. To achieve this, Phase 3D will employ four deployable solar panels in addition to the two mounted on the spaceframe. This will be the first use of deployable panels on an amateur satellite. Of course, deployable panels means mechanisms to initiate the unfolding plus appropriate hinges and latches to achieve the desired final configuration. The answer to the right type of hinge was found at the entrance to German bistros, the same kind of device seen in old-style North American western saloons - the cabaret hinge. This type of hinge is able to swing both ways but always return to the desired center position. One of the German members of the Phase 3D Design Team first suggested the use of this type of hinge, and actually obtained one at a German hardware store to demonstrate the utility of the principle on the model of the former Phase 3D "Falcon" spacecraft design. As there is not the luxury of a lot of excess space around the current Phase 3D spacecraft when installed in the Ariane 5 launch vehicle, this hinge design had to go through several gestations in order to achieve the desired device in a compact manner. This effort included finding a spring wire able to withstand the metallurgical and thermal rigors of anticipated operation at temperatures as low as -100°C .

Power System

Since satellites must get their primary power from a source other than the local power company, some means of carrying energy on board, or using the sun, is required. Currently, the only practical means of obtaining power, open to amateurs and most other satellite designers, is the use of solar panels. As stated above, generating the power needed to support the transmitters aboard Phase 3D requires large solar panels. The design which evolved calls for a total solar panel area of 4.46 m^2 (48 ft^2) and solar cells of 14.3% efficiency. This array will produce about 620 Watts of power at the beginning-of-life (BOL) and at optimum sun angle ($\beta=0^{\circ}$). After 10 years in orbit, this power number will still be about 350 Watts at a $\beta=45^{\circ}$. This amount of power is still sufficient to operate at least two transmitters and the other necessary spacecraft systems. Like almost anything else, solar arrays deteriorate with age. This is why their performance after a specified number of years is an important design consideration. The cells for Phase 3D are being obtained through a very attractive agreement with DASA, the German Space Agency. While other sources and configurations of solar cells were considered, it was concluded that this one represents the best trade-off between performance and cost. Solar cells represent one of the single highest cost items which go into building a spacecraft.

While solar panels are satisfactory as a sole source of power, some form of energy storage must also be provided. This is accomplished with a battery. Energy storage is necessary, not only to power the spacecraft during times that the sun is eclipsed by the earth, but also to operate the arc-jet thruster, described later. Its power requirements exceed the capability of the solar arrays, even under the best of conditions. Actually the Phase 3D satellite will carry two batteries, a "main" and an "auxiliary". This is to provide redundancy in case of failure of the main battery. The Phase 3D design team evaluated several sources and types of batteries. A final decision was made to select a more or less conventional nickel-cadmium battery, albeit with a new plate design, as proposed by a German firm. Another contender was from a U.S. firm which proposed the use of an assembly of Nickel-Metal Hydride cells for the main battery and a more conventional Nickel-Hydrogen stack for the auxiliary. As in the case of the solar cells, cost was an important factor in reaching this decision.

Transmitters

In addition to challenging the spacecraft power system, higher power transmitters also require careful circuit design, particularly at the microwave frequencies. High power, at microwave frequencies, is hard enough to come by in itself, but in a satellite, more difficult yet. In order to produce relatively high power, and live within the tight power budget imposed by satellite's power system, high efficiency RF power amplifiers are a must. However, attaining high efficiency, particularly at microwave frequencies, is a formidable task. Fortunately, the amateur community has already addressed this problem. It is called "HELAPS" and stands for High Efficiency Linear Amplification by Parametric Synthesis. This concept has been proven on the 2 meter and 70 cm transmitters employed in AMSAT satellites since OSCAR 7.

HELAPS will be a mainstay on the high power amplifiers used in the 70 cm (U Band) and 13 cm (S Band) transmitters aboard Phase 3D. Designing such amplifiers is a very exacting process, and an approach not understood by very many microwave designers - amateur or commercial. Design, construction, troubleshooting and final checkout of these amplifiers is one of the major tasks that confronted the Phase 3D design team.

Receivers

Phase 3D will have receivers for at least 2 meters (V Band), 70 cm (U Band) and 23 cm (L Band). In addition, receivers for 15 meters (H Band), 2.4 GHz (S Band) and 5 GHz (C Band) are slated to be included.

Link Performance

Another of Phase 3D's design features, intended to accommodate smaller ground stations, is the use of spacecraft antennas with higher gains than employed on previous amateur satellites. However, there is a limit to how much gain is desirable. If full Earth coverage is to be provided, there is a limit to how much

antenna gain can be used. At Phase 3D's apogee of 48,000 kilometers, the Earth will have a diameter of approximately 13 degrees. A half power beamwidth of 13 degrees corresponds to a gain of approximately 20 dBi. On a 2.5 meter (8 feet) diameter satellite, such gain cannot be achieved on 70 cm or lower. But, for 2.4 GHz and above, antennas with such gains are small enough to be accommodated. Thus, above 1.26 GHz antenna gain is limited by the desire to provide full Earth coverage, while on the lower bands it is driven by available spacecraft real estate.

If one considers a ground station with a particular fixed parabolic antenna size, the effective link attenuation on the various microwave bands is the same on each. The rise in antenna gain with frequency compensates for the greater attenuation, the so called "wavelength factor". In reality, the difficulty of producing RF power on the higher microwave frequencies, for example 10.5 GHz and above, as well as the greater antenna pointing precision required, (receiver sensitivity being no longer a significant factor at least up to 10 GHz), results in a preference for the lower microwave bands. On the VHF and UHF frequencies the links tend to be less favorable, as the lower satellite antenna gain has its effect on link performance. In addition, the effective noise temperature is higher at the lower frequencies. Of course, some of these disadvantages can be overcome by higher transmitter power which is easier to come by as one goes to lower frequencies. Nevertheless, it is expected that the microwave links on Phase 3D will significantly outperform those on the lower bands and will become more and more popular as time passes.

IF Matrix

The IF matrix provides the facility to be able to connect, under control of the IHU, any receiver with any transmitter. It also includes the LEILA, discussed in the following section. The IF frequency is 10.7 MHz and the matrix has an input and output level of -15dBm.

LEILA (The Alligator Eater)

One of the problems faced since the first transponder amateur satellites has been that of the "power hog", sometimes also referred to as an "alligator". This is a ground station which uses much more power than necessary to produce a useful signal through the satellite. In the past, the only recourse, other than turning the satellite OFF completely, was to warn the offending individual or refuse to talk to the person. But Phase 3D will incorporate a circuit designed to counter "power hogs". It's called LEILA which stands for LEistung Limit Anzeige (in German) or Power Limit Indicator as a suitable translation. The circuit works at the spacecraft's main IF, and thus is available to all uplink/downlink combinations. If a signal above a certain threshold is detected, LEILA will first put a Morse transmission on the frequency. It might say something like "PSE QRP". If that does not cause a reduction in the strength of the signal, LEILA will place a notch on the frequency - which should accomplish the objective. A block diagram of LEILA is shown

in Fig. 3.

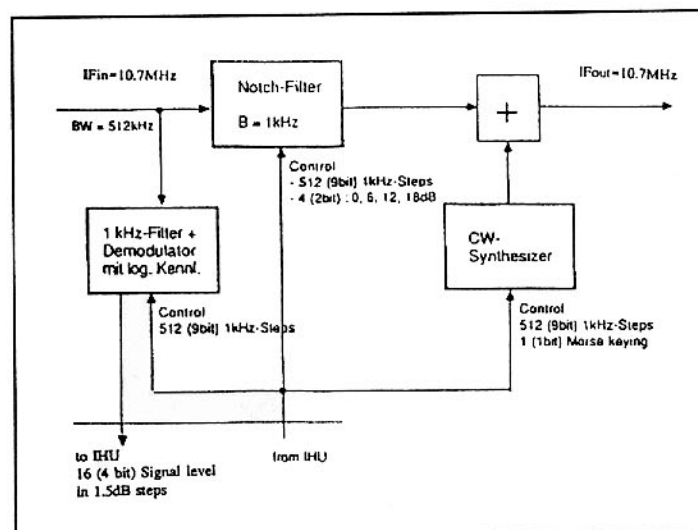


Figure 3
LEILA Block Diagram

Antennas

The subject of antenna design has been a major thrust in the Phase 3D effort. Since Phase 3D will incorporate receivers and transmitters on many bands, a number of antennas will be required. Optimizing the gain in accordance with the considerations of the preceding section, and/or reducing the size of each of these antennas, was another of the major challenges that faced the Phase 3D design team. Because of launch vehicle constraints, effort was concentrated on the use of low profile circularly polarized antennas. Table 3 lists the types of antennas which have been designed to meet the needs of Phase 3D for the various bands.

As the launch date approaches, the team effort is to transform antenna theories and prototypes into flight hardware. The computer design work is complete as well as the construction of prototype antennas. The feed systems are designed and the required relays selected. Most of the coaxial cable and connectors are already at the integration facility for installation on the spaceframe. The 10 meter antenna design is complete with only the fabrication of the flight hardware to be accomplished.

On V Band, a $1/4\lambda$ flexible open sleeve antenna will be used for the omni. The final design of this antenna has been established. The V Band high gain antenna design is finalized with prototype testing almost complete. The transmission line to both V Band antennas employs a 4-port relay to interchange the transmitter and receiver between the omni and high gain antennas.

The first U Band patch antenna is now bonded on an inner top panel of the spacecraft. Tests show it to be slightly low in

frequency. The impedance is 49.4 ohms on the resonant frequency. The U Band omni antenna consists of a pair of $1/4\lambda$ whips mounted on opposite sides of the V Band whip.

A prototype L Band Short Back Fire (SBF) antenna is presently under test. It consists of a 21 cm diameter cavity with a $1/4\lambda$ high wall forming the cavity. It is, actually, an aluminum pizza pan, the kind you can buy in the housewares department of any department store. AMSAT's policy is to use readily available, inexpensive, hardware when it is adequate to serve the purpose. The feed is a turnstile feed with a split-feed balun and mounted $1/4\lambda$ above the floor of the cavity. A 0.6λ reflector is mounted $1/4\lambda$ above the turnstile. The antenna is similar to a parabolic dish but is easier to build and has more gain at the smaller diameter. The L Band Omni is a pair $1/4\lambda$ vertical stubs mounted next to the V Band and U Band whips. The flight models of the S Band and C Band Parabolic Dish Antennas are in hand. These are commercial spun aluminum dishes with feed horns designed for Amateur frequencies. The highest frequencies, 10.45 GHz (X Band) and 24 GHz (K Band), will employ conical horn antennas with gains in the 20 dBic range. These will be provided by the constructors of the respective transmitters and mounted directly on the units, protruding through the top of the spacecraft.

Table 3
Phase 3D Gain Antenna Configurations

Operation Band	Antenna Type	Gain
15 M (H Band)	Same as 10 M	0 dBi
10 M	2 El. Deployed Whip	4.5 dBi
2 MHz (V Band)	3 Low Profile Dipoles	10+ dBic
435 MHz (U Band)	6 El. Patch	13+ dBic
1269 MHz (L Band)	Short Back Fire	15+ dBic
2.4 GHz (S Band)	Parabolic Dish	18-20 dBic
5.6 GHz (C Band)	Parabolic dish	18-20 dBic
10.45 GHz (X Band)	Dual Horn	20 dBic
24 GHz (K Band)	Horn	20 dBi

Spacecraft Computers

The Phase 3D satellite incorporates a primary and several secondary computers. The main computer, the "IHU" mentioned earlier, is the main spacecraft computer and is tasked with running all aspects of the satellite from power management to attitude maintenance. It is the IHU which will command the turning ON and OFF of transmitters, the switching of antennas etc. It is similar in design to the IHU used on OSCAR-13. As AO-13 does, it employs a radiation hardened 1802 COSMAC processor. While this is a rather "old" CPU unit, and performance improvements might have been achieved by the use of newer technology, it was decided that it would adequately serve the needs of Phase 3D. It has the advantage of being a "known quantity" with much of the needed software already in hand. The old adage, "If it ain't broke, don't fix it" was applied. The Phase 3D IHU incorporates an eight-bit analog-to-digital converter for analog measurements (voltage, power, temperature, current, and the like). It has fifty-six independent input and output bits for measurement and control.

Some of these bits are used internally, but most are brought out to connectors to route to the rest of the spacecraft. The AO-13 scheme to allow multiplexing many of these bits was expanded for the additional I/O requirements of Phase 3D.

The primary differences between the older IHU and the Phase 3D design may be summarized as follows:

1. Phase 3D has 64k bytes of error-detection-and-correction (EDAC) memory, compared to 32k bytes for AO-13.
2. The physical size of the IHU modules is different. The one used in AO-13 measures 200mm x 300mm, whereas the Phase 3D module is smaller - 200mm x 270mm.
3. The AO-13 IHU occupied two double-sided PC boards with a wiring harness joining them and attaching the connectors to the rest of the spacecraft, while the Phase 3D IHU is on a single, multi-layer PC board with all connectors soldered directly to the board. There is no internal wiring harness in the Phase 3D IHU.
4. The AO-13 IHU required a separate command decoder, housed in a separate module. The Phase 3D IHU incorporates the command decoder on its PC board.
5. The Phase 3D IHU also incorporates an experimental networking adapter called the Controller Area Network (CAN) Bus. This is based on an automotive standard widely used in Europe and Japan as well as the U.S. The CAN bus will be used to tie the IHU into the other spacecraft computer-based systems.

RUDAK

In addition to the IHU, Phase 3D will include a digital communications experiment, called "RUDAK". RUDAK is an acronym from the German "Regenerativer Umsetzer für Digitale Amateurfunk Kommunikation." In case your German is a bit rusty, this translates to "Regenerative Transponder for Digital Amateur Radio Communication." The name is from the RUDAK experiment built by Amateurs in Germany and flown on AO-13.

An improved RUDAK was flown on AO-21. On that spacecraft, it was used for some time in an "FM Repeater" mode; receiving FM voice transmissions on 70 cm, digitizing and processing them, and finally retransmitting them as FM voice modulation on 2 meters. This mode became quite popular and did much to bring satellite operation to amateurs not heretofore familiar with it. Unfortunately, AO-21 ceased operation in October 1994.

The RUDAK to be flown on Phase 3D is being designed, constructed, programmed and commanded by an international team from North America and Europe. It is aimed at providing packet-based communication, similar to that performed by the existing MICROSATS and UoSats, early in the operational life of the satellite. However, it has also been designed to allow

changes in the way Amateurs use digital communications satellites as time passes.

The Phase 3D RUDAK actually consists of two computers. One is based on the NEC V53 processor. It has numerous serial communications ports using direct memory access (DMA) techniques and incorporates 16 megabytes of memory for program and data storage. A portion of this memory uses EDAC for integrity. The second computer is based on the Intel i386EX processor and has its own memory array; likewise using EDAC. It also uses DMA-based serial I/O ports for communications.

Each RUDAK processor is equipped with 9600 bit/sec hardware FSK modems for compatibility with existing digital satellites. In addition, a total of eight DSP-based, frequency-agile modems are being incorporated to allow support of other modulation techniques and communications systems. In this way, RUDAK is aimed at avoiding obsolescence over the expected 10 to 15 year life of Phase 3D. In addition to the tasks outlined above, RUDAK will be used in conjunction with the GPS and SCOPE experiments.

Orbit

Another important aspect of the Phase 3D project is the selection of the final orbit for the satellite. Like all of the other design considerations, it too has been engineered to bring the most benefit to as many amateurs throughout the world as possible. Like OSCARs 10 and 13, it will go into a highly elliptical orbit of the Molniya variety. But there, the similarity ends. The apogee (high point of the orbit) for Phase 3D will be much higher than the previous satellites - about 48,000 km versus 36,000 km. The perigee (low point) will also be higher, about 4,000 km. This yields an orbital period of 16 hours. The significance of this will soon become apparent.

Because the Earth rotates once every 24 hours (twice in 48 hours), a 16 hour orbit results in three complete orbits in the same 48 hours, or two days. This two day repetition will make it much easier for us mortals to remember when Phase 3D will return to the same position. Furthermore, because of the 16 hour orbital period, Phase 3D goes through an apogee every 16 hours. In this time, the Earth rotates 240° or 16 time zones. The orbit will be such as to place one apogee over North America, one over northern Europe and one over the Far East. Because of this synchronism between the satellite's orbit and the Earth's rotation, it will go through apogee at approximately the same local time in each area every two days. To illustrate how this will work, take the example of an amateur in the Midwest section of the country. Phase 3D will be visible for many hours, at a high elevation angle, centered on say 8:00PM. It will then drop rapidly and reappear 16 hours later over Asia. But it will be high enough so that it will be within sight of this Midwest location. Thus it will appear to rise rapidly in the northwest and hang for a number of hours and then drop very suddenly. Sixteen hours later it will do the same thing, this time in the northeast during its European apogee. But the local times for each apogee will always be centered on 8:00 PM - a peak time

for amateur activity.

Put the elements from Table 4 into your tracking program and see how Phase 3 will behave at your location.

Table 4
Phase 3D Orbital Elements

1991	
Epoch	91 80.00000000
Epoch Rev.	1
Mean Anomaly	0.0000000000°
Mean Motion	1.5000000000
Inclination	63.4343490°
Eccentricity	0.67743780
Argument of Perigee	220.000000°
Rt.Ascension of Ascen.Node	225.000000°

Of course, some of these elements may vary somewhat from the final orbit Phase 3D attains, but they will serve to illustrate what tremendous potential the new bird holds.

GPS Subsystem

Phase 3D will be one of the first satellites, amateur or otherwise to utilize the GPS satellites. It will be the first to do so in a high elliptical orbit. As used on Phase 3D, GPS will have the following uses. First, it will enable the satellite to determine its own orbit, put this information into the form of Keplerian elements and transmit them to us here on the ground via the telemetry system. In addition, as noted earlier, it will serve as a back-up to the Sun and Earth sensors to provide orientation information.

The GPS Subsystem, consists of an array of eight L-Band antennas (four on the "top" and four on the "bottom") and a 24-channel GPS receiver using digital signal processing techniques. Any of the eight antennas can be electrically connected to any of the 24 receiver channels, and unused resources can be powered down.

The L-band signals from the eight antennas are amplified and routed to the RF portion of the GPS module. The RF sections consists of eight single chip (Plessey GP-1010) downconverters. These chips are optimized for GPS use and are complete triple-conversion microwave front ends, incorporating phase-locked local oscillators.

Each of the eight RF sections provides a digital output stream (2-bit sampled) for processing in an array of four VLSI Correlator ICs (Plessey GP-1020). The purpose of the correlators is to extract the weak, spread-spectrum GPS signals and include the final local oscillator and spreading code generators; the correlator chips average the weak signals to improve detection. They then present the output data in a format suitable for processing by a computer. The computer is based on the AMD 29200 RISC controller. This is a 32-bit RISC machine with high throughput for the demanding real-time filtering and position solution calculations required. Like all the other computers aboard Phase 3D, the 29200's memory has EDAC protection. The

29200 CPU completes the digital signal processing of the GPS signals and closes the final phase- and code-locked tracking loops in the GP1020 correlators.

All the oscillators -- the phase-locked LOs in the GP1010 chips and the phase- and code-locked loops in the GP1020 chips -- are derived from a high-stability crystal oscillator operating at 10.000 MHz. The 10 MHz signal is also counted down to provide long-term high-stability clock functions.

Data from the GPS experiment will be accurate enough to determine the Phase 3D orbit to within 10-20 meters accuracy. This knowledge will be especially important for evaluating the performance of the arc-jet motor. When operating to determine the spacecraft attitude, the GPS experiment will provide supplementary sensor data accurate to within 0.1 to 0.2°. At the same time, the GPS experiment will know UTC time to an accuracy of better than 1 µsec.

The GPS unit will communicate with the rest of the spacecraft via the CAN bus, and has a dedicated serial link to RUDAK for backup purposes. It will rely on these data links for controlling its operation, for loading new software, and for sending data to the ground. It is planned that the GPS experiment will send <UI> packet radio frames to the user community giving the GPS-derived Keplerian elements, spacecraft attitude data as well as experiment housekeeping telemetry.

Propulsion Systems

To move the spacecraft, from the low-inclination initial orbit provided by the Ariane 5 launcher, to its final orbit, and keep it there, Phase 3D incorporates two propulsion systems. The primary system is a high thrust bi-propellant liquid rocket motor with its associated tankage, plumbing and control circuitry. The other is a much lower thrust Arc-jet system mentioned earlier.

The bi-propellant 400 Newton propulsion system is a repackaged version of the one used successfully in the OSCAR 10 and 13 projects. It incorporates a 400 Newton (95 pound) thruster, being provided by a German aerospace company, that utilizes Mono-Methyl-Hydrozine (MMH) for fuel and nitrogen tetroxide (N_2O_4) for the oxidizer. Because of the higher mass of the Phase 3D spacecraft, multiple tanks are required to carry the quantity of propellant required for this mission - over 60 kilograms of MMH fuel and 130 kilograms of N_2O_4 oxidizer. The plumbing used to transfer the propellants from the tanks to the thruster has been designed for simplicity but with sufficient redundancy to assure safety and reliability. Helium gas from a high pressure storage tank is regulated to a lower pressure by the pulsing of an electrically operated valve referenced to a pressure transducer, used to pressurize the propellant tanks through redundant check valves and feed the propellants to the thruster. A second electrically operated valve in series with the first is ready to take over should the first fail.

The electronics module that controls the motor ignition and burn sequence is the Liquid Ignition Unit (LIU). This module

contains the circuitry required to validate coded firing commands, initiate the firing sequence by opening and pulsing the Helium isolation valves, control pressure in the propellant tanks, open the motor valves, clock the commanded motor burn time and safe the system at the end of burn. This basic system has already proven fully capable of supporting the multiple burns necessary to place the Phase 3D spacecraft in its final orbit.

To provide for stationkeeping and minor adjustments once the spacecraft is in final orbit, a small arc-jet thruster is also being incorporated in Phase 3D. Compared to the 400 Newton thrust of the primary propulsion system, this motor puts out a puny 100 milli-Newtons, but it does this at very high efficiency over very long burn times. This is accomplished by striking an electrical arc at the tip of the motor, then feeding a small quantity of gaseous ammonia fuel through the arc heating it to very high temperatures, and thus causing it to rapidly expand, and thereby providing highly efficient thrust. The arc-jet thruster will make possible a long-term capability to perform minor orbit adjustments to correct for the kind of orbit instabilities introduced by lunar and solar perturbations that are causing the predicted reentry of the OSCAR 13 spacecraft in late 1996. Extended testing of the system has been successfully completed at the University of Stuttgart. A plumbing system will convey ammonia from propellant tanks, heat it to a gaseous state and meter its flow to the thruster. An electronic module supporting the Arc-jet will provide the approximately 1 kW required to initiate and maintain the arc. It will also provide the electronics necessary to initiate, time and terminate the thruster's burn.

Spaceframe and Launch Adaptor

Naturally, all of this equipment must be housed in something. That something is the spaceframe. Spacecraft payload specialists always insist that the spaceframe should weigh nothing, and the structural engineers always want to construct the strongest "battleship" to withstand the rigors of the launch environment. This is a technological version of an age-old head-butting confrontation. In the case of Phase 3D, those designing and building the structure were continuously urged to do better and better. Along the way a number of quite good lessons on light-weight aircraft structural construction methods were learned. While the end product is not as light as some would have liked (about 60 kg), it has already demonstrated itself to be very strong. The spaceframes for OSCARs 10 and 13 weighed only 7 kg, and that fact was held over the heads of the structure design and construction team like a sword of Damocles!

The Phase 3D spaceframe is principally fabricated of thin-gauge sheet aluminum. Its formation, to rather unusually close tolerances for sheet metal structures, caused more than passing concerns by all who were involved in the effort. Typically these tolerances are in the range of $\pm 0.2\text{mm}$ ($\pm 0.008\text{in.}$). The secret to this type of construction is to place all of the load stresses into the shear plane of the sheet metal, where it is notably strong for its weight. An example of this are the six Divider Panels, one on each corner of the spaceframe. Three of these will be anchored to the launch vehicle which will get Phase 3D into

space. Thus, during launch, these three points will be quite heavily loaded in all motions. The only machined parts in the spaceframe are the six Corner Posts at the outer ends of the Divider Panels. These must be robust enough to carry all of these launch thrust loads into the spaceframe, translating all of those forces into the plane of the 0.8mm thick sheet metal Divider Panels as shear forces. It is difficult to completely convey these concepts in words and pictures, but those seeing the spaceframe in-person will be able to more readily grasp the concepts employed in the design.

SBS

Since Phase 3D will be a secondary payload on the Ariane 5 launch vehicle, it must conform to whatever space the European Space Agency (ESA) can make available. ESA already has a conical adaptor which interfaces between the 2624 mm diameter bolt circle on the Ariane upper stage to a 1194 mm diameter clamp-band used for payloads. However, although hollow, the conical adaptor does not provide sufficient space to house Phase 3D, or any other reasonably sized payload. Accordingly, ESA offered the amateur satellite community the opportunity to launch aboard the new, big vehicle if we would provide a cylindrical "spacer" that could be mounted between the 2624 mm diameter bolt circles on the bottom and the conical section on the top. Phase 3D could then ride to orbit inside this cylinder. But that's not all. ESA also wants to be able to launch another satellite on the same mission, which would sit on top of the conical adaptor. Thus, they require that our cylindrical section must be able to support the launch loads of this other fellow passenger. This means that this 2624 mm diameter Specific Bearing Structure (SBS), which we must produce, must be able to withstand the load forces imposed by a 4.7 metric ton (10,350 lb.) satellite load. In order to assure ourselves that our design is capable of handling such a load, extensive computer analyses have been performed (on the same home computer used to accomplish the thermal analysis).

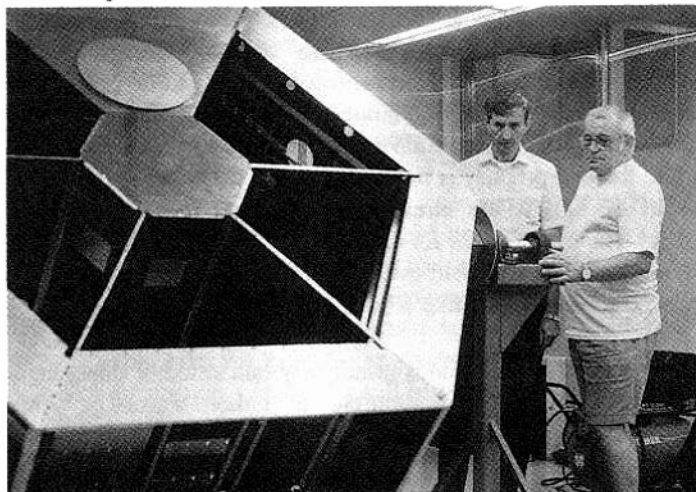


Figure 4

Stan Wood WA4NFY (L) & Konrad Müller DG7FDQ examine Phase 3D on its assembly cart at the Orlando Integration Facility. Note 70cm patch antenna on one of the top panels. (WD4FAB.photo)

Construction of the 2624 mm diameter SBS began with the ordering of machined aluminum rings, called Frames, for the top and bottom of the cylinder that form the bolting flanges. This is a single-piece machining that is about 8-1/2 feet in diameter with a pattern of 244 bolts and 488 rivets for each 2624 mm diameter Frame. These have now been delivered to Weber State University in Utah, where construction of the SBS is taking place on a specially fabricated steel table machined, measured and adjusted to be flat to ± 0.05 mm (± 0.002 inch). This degree of precision is necessary to insure that the SBS will be a "true" structure that will fit to the other components of the load-carrying composite "stack" that support the prime payloads.

On the interior of the SBS, we will provide a supporting structure for the Phase 3D spacecraft. Three of these structures will terminate in three high-strength bolts that are attached to the spaceframe. These bolts each have concentrically mounted springs to provide the "push-off" forces needed to separate Phase 3D from the launch vehicle, with a velocity of 0.5 meters/sec.

These bolts hold the satellite to the SBS with three pyrotechnically operated nuts. The nuts are opened on electrical command to separate Phase 3D from the launch vehicle.

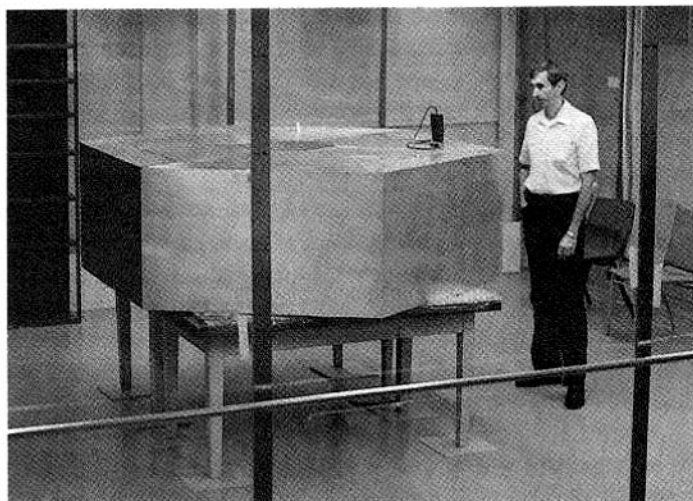


Figure 5

Stan Wood WA4NFY makes acoustic noise measurement on the Phase 3D spaceframe in the Orlando, Florida Integration Facility clean room. (WD4FAB photo)

Operating Schedule

Reference to Figure 2 shows that any of the uplink receivers can be cross-linked to any downlink transmitter, except for the 29 MHz transmitter, which is a single channel affair intended only for the transmission of bulletins. However, there are two factors which limit which uplinks can be linked to which downlinks. One of these is the power required for the various downlink transmitters. As stated earlier, Phase 3D will have an average power generation capability of about 600 watts at the beginning of life, decreasing to about 350 watts after about 10 years or so, as the solar cells age. Thus, even after 10 years, it is still

expected that the solar arrays will be capable of producing enough power to run at least two transmitters simultaneously. As the onboard receivers require very little power, they are not a factor. So it is expected that multiple receivers can be operated simultaneously. Therefore, it is apparent that the uplink and downlink combinations, that will be simultaneously available, are limited only by onboard power and the obvious fact that it will not be possible to have an uplink and a downlink activated in the same band at the same time. This will preclude Configurations such as V/V or U/U.

The specific combination of uplinks and downlinks activated in at particular times will be determined by a governing group called "The Program Board". This group will be composed of a single representative from each organization that has, by the time of launch, contributed a specified substantial sum of money toward construction of the satellite. Currently, this Board includes AMSAT-DL, AMSAT-NA, AMSAT-UK, the German Amateur Radio League (DARC) and the American Radio Relay League (ARRL). Decisions of the Program Board will be carried out by the various command stations that will be set up around the world to watch over the health of the satellite and send it appropriate commands to maintain the operating schedule established by the Program Board as well as to insure Phase 3D's continued proper operation.

A Team Effort

From what has been said in this article, it is apparent that the design, construction, management and financing of the Phase 3D satellite is an international team effort. Without the cooperative effort of all of those involved, this ambitious project could not be completed. Whether it is the scientists and engineers who come up with the innovative design approaches, the technicians who fabricate the various spacecraft component parts, those who coordinate the arrival of these parts at the required time, or those who have made financial donations, all participants on this team are contributing to the successful completion of Phase 3D. When it is put into orbit on ESA's huge new Ariane 5 heavy lift launch vehicle in April 1996, everyone who participated can take justifiable pride in their accomplishment. Because of the dedication of these selfless individuals, Amateur Radio will be presented with a significant new resource for use well into the next century.

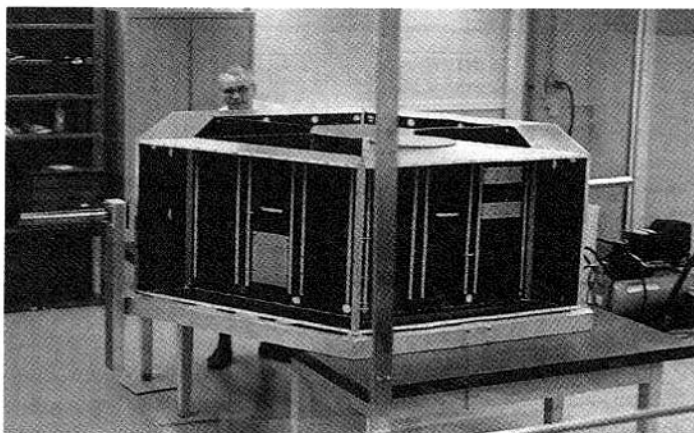


Figure 6

Konrad Müller checks the fit-up of the spaceframe panels onto the heat pipes. (WD4FAB photo)

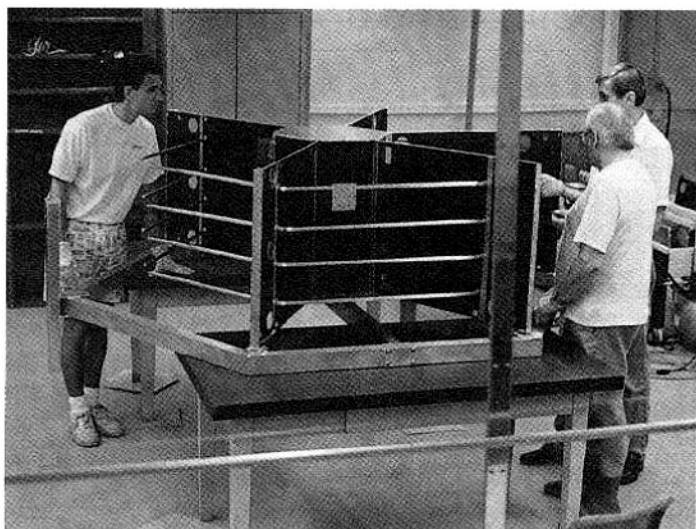


Figure 7

The first step in the assembly of Phase 3D - The heat pipes and five of the divider panels have been "intertwined" and attached to the central cylinder. The three admiring their work are Konrad Müller DG7FDQ (foreground), Frank Lavra (L) and Stan Wood WA4NFY (WD4FAB photo).

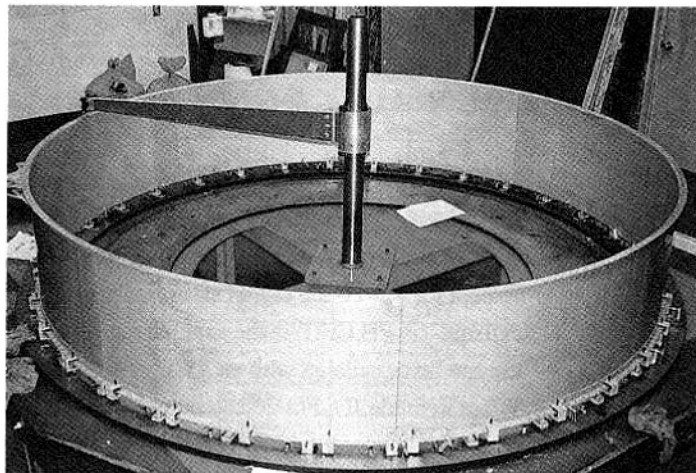
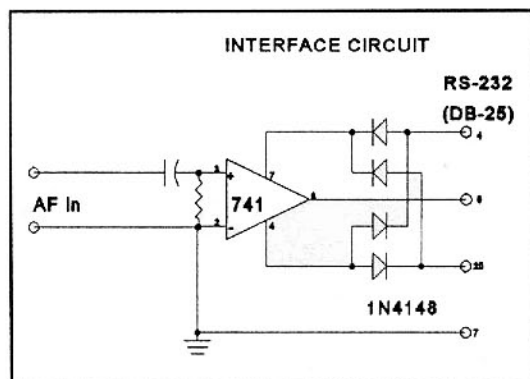


Figure 8

The Specific Bearing Structure (SBS) under construction at Weber State University Ogden, Utah. Phase 3D will be housed in the SBS during its ride to orbit. (Photo by Ralph Butler of Weber State University)



Correction: The schematic that was included with last month's SSTV article was so light that the input capacitor was not displayed properly. Note it is in series with the audio input line.

BOARD OF DIRECTORS NOMINATIONS

The time has again come to submit nominations for the AMSAT Board of Directors. AMSAT Member Societies, or five individual members may make nominations of fellow AMSAT members to serve two year terms. Four seats on the seven member Board must be filled this year. The four current Board members whose terms are expiring are: Keith Baker KB1SF, Dick Daniels W4PUJ, Junior de Castro PY2BJO and Bill Tynan W3XO. Be sure that anyone you nominate agrees to serve and understands that meeting attendance is necessary. There are generally two Board meetings per year - spring and fall. Nominations should be marked "BOD Nomination" and be sent to: AMSAT, 850 Sligo Ave, Suite 600, Silver Spring, MD 20910 and must arrive by JUNE 15, 1994.

Current Amateur Satellite Frequencies

Satellite	Callsign	Uplink	Downlink	Type
AO-10		435.03-435.18 LSB/CW	145.975-145.825 USB/CW	Mode B Analog
AO-13		435.423-435.573 LSB/CW	145.975-145.825 USB/CW	Mode B Analog
AO-13		435.603-435.639 USB/CW	2400.711-2400.749 USB/CW	Mode S Analog
FO-20		145.9-146.0 LSB/CW	435.9-435.8	Mode J Analog
AO-27		145.85 FM	436.80 FM	Part-Time Repeater
RS-10		145.865-145.905 USB/CW	29.360 - 29.400	Mode A Analog
RS-12		21.21-21.25 USB/CW	29.41-29.4	Mode K Analog
AO-16	PACSAT	145.90, .92, .94, .96 FM	437.0513 SSB	1200 Baud PSK
DO-17			145.825 FM	1200 Baud AFSK/ voice
WO-18			437.104 SSB	1200 Baud PSK (img)
LO-19	LUSAT	145.84, .86, .88, .90 FM	437.1258 SSB	1200 Baud PSK
FO-20	8J1JBS	145.85, .87, .89, .91 FM	435.91 SSB	1200 Baud PSK
UO-22	UOSAT5	145.9, .975 FM	435.12 FM	9600 Baud FSK
KO-23	HL01	145.85, .90 FM	435.175 FM	9600 Baud FSK
KO-25	HL02	145.87 FM	436.5 FM	9600 Baud FSK
IO-26	ITMSAT	145.875, .90, .925, .95 FM	435.822 SSB	1200 Baud PSK
POSAT	POSAT1	145.975 FM	435.2777 FM	9600 Baud FSK

- 1) Frequencies shown are without Doppler compensation. For typical digital satellite pass the original signal will be about 8 kHz higher than what is shown.
- 2) WO-18 Webersat transmits experimental and image data and can be captured in KISS mode via PB or TLMDC.
- 3) Except for FO-20 the digital sats use a program suite containing PB/PG/PFHADD/PHS or WISP. The broadcast callsign (in PB.CFG) is the satellite's callsign with an SSID of -11. The connected mode callsign (in PG.CFG) is the satellite's callsign with an SSID of -12.
- 4) When in mode JD, FO-20 can be worked with any packet program. Connect to 8J1JBS. FO-20 currently alternates between modes JA and JD on a weekly basis. Check ANS bulletins for schedule.
- 5) AO-10 is no longer controllable but the transponder works when the satellite is in sunlight.
- 6) For AO-10 and AO-13, transmit LSB, receive USB. As transmitted frequency is increased the received frequency will decrease (inverting transponder).

Launch Opportunities Beyond Phase 3D

This article was first published in the Proceedings of the AMSAT-NA 12th Space Symposium, October, 1994 in Orlando, Florida.

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AMSAT has always relied on the kindness of strangers, especially where launch services are concerned. The earliest OSCARs were carried as piggyback pay-

loads, often replacing ballast which would have been required to meet the primary payload's objectives. Those opportunities have all but disappeared with the evolution of commercial launch vehicles. Excess launch vehicle capacity is now used to put satellites into more precise or efficient orbits, eliminating unused capacity. In cases where there is room for additional satellites that space is now sold to commercial customers, anxious to use microsats. The Phase 3 satellites have all obtained rides on new versions of Ariane launch vehicles, prima-

rily due to AMSAT-DL's excellent relationship with the European Space Agency. But Ariane 5 is planned to be the workhorse for European launch vehicles well into the next century, limiting our launch opportunities there. So where can we find future rides into space?

Here's several opportunities which we missed, for one reason or another:

In two cases satellites were launched from the shuttle where the upper stages had plenty of excess performance which we

Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	RS-12/13	RS-15
Catalog Number	14129	14781	18129	19216	20480	21089	23439
Epoch Time	95045.85960153	95046.56017156	95046.22156292	95045.47450518	95043.19594349	95045.86946859	95046.54824140
Element Set	339	775	21	15	769	776	29
Inclination	26.5694	97.7806	82.9265	57.6414	99.0672	82.9219	64.8134
RA of Node	282.8718	54.8195	149.2197	203.8202	155.0645	191.4712	91.7100
Eccentricity	0.6019168	0.0011082	0.0013311	0.7262952	0.0540527	0.0029367	0.0167780
Arg of Perigee	252.4242	207.0415	70.0222	2.1919	156.0508	149.8997	283.1671
Mean Anomaly	36.3604	153.0216	290.2367	359.5469	206.6776	210.3850	75.0580
Mean Motion	2.05878612	14.69304196	13.72348199	2.09725598	12.83230064	13.74054117	11.27525542
Decay Rate	.00000205	.00000112	.00000038	-.00000472	.00000006	.00000048	-.00000039
Epoch Rev	8778	58604	38324	5108	23491	20197	580
Satellite	UO-14	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23
Catalog Number	20437	20439	20440	20441	20442	21575	22077
Epoch Time	95043.24574911	95047.21076680	95043.78280625	95047.19104907	95043.23455558	95043.22913170	95043.33449374
Element Set	74	873	872	877	872	578	470
Inclination	98.5769	98.5863	98.5877	98.5872	98.5865	98.4110	66.0763
RA of Node	129.6029	135.0196	132.0509	135.3952	131.8118	117.5700	137.1671
Eccentricity	0.0010135	0.0010557	0.0010735	0.0011229	0.0011507	0.0007319	0.0012579
Arg of Perigee	204.3407	192.8871	202.4941	192.6688	203.9363	302.0114	230.1761
Mean Anomaly	155.7287	167.2043	157.5771	167.4212	156.1286	58.0358	129.8142
Mean Motion	14.29874443	14.29928687	14.30069215	14.30041655	14.30141684	14.36958381	12.86290017
Decay Rate	.00000014	.00000017	.00000013	.00000018	.00000035	-.00000005	-.00000037
Epoch Rev	26389	26447	26400	26449	26394	18755	11767
Satellite	AO-27	IO-26	KO-25	POSAT	MIR	MET-2/17	MET-3/2
Catalog Number	22825	22826	22828	22829	16609	18820	19336
Epoch Time	95043.69990406	95045.69548085	95043.75843484	95043.69810586	95047.20976127	95046.52900362	95046.80509661
Element Set	369	368	346	361	939	541	371
Inclination	98.6313	98.6303	98.6274	98.6283	51.6471	82.5389	82.5419
RA of Node	121.8081	123.8530	121.9697	121.9368	43.9703	75.0329	151.3061
Eccentricity	0.0007646	0.0008239	0.0009543	0.0009252	0.0004454	0.0015302	0.0018108
Arg of Perigee	227.1331	222.0688	210.6307	212.2460	129.0857	213.3417	16.6993
Mean Anomaly	132.9210	137.9858	149.4317	147.8157	231.0525	146.6779	343.4720
Mean Motion	14.27650866	14.27757931	14.28086521	14.28063337	15.57632655	13.84731409	13.16971478
Decay Rate	-.00000015	.00000001	.00000009	-.00000007	.00005408	-.00000001	.00000051
Epoch Rev	7200	7229	4011	7202	51417	35603	31532

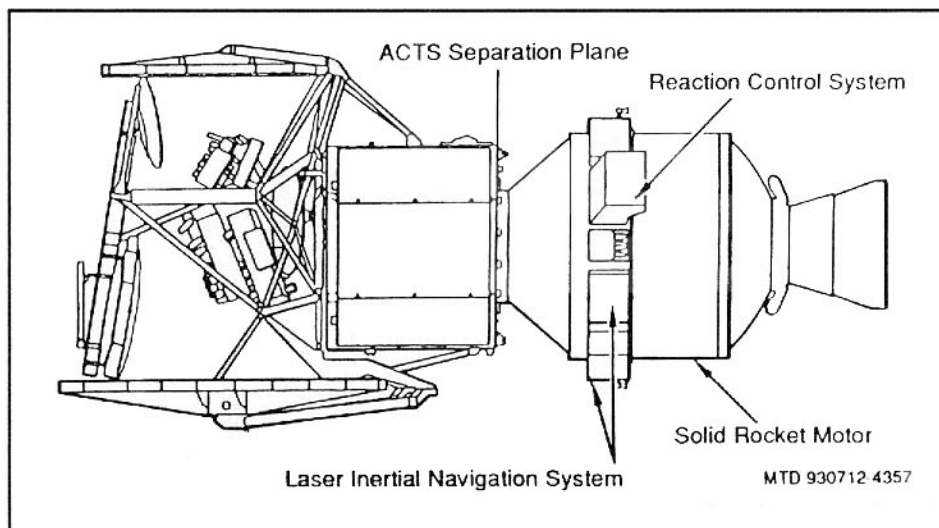


FIGURE 1 - STS-51 ACTS/TOS configuration

could have theoretically used. In the mid 1980s start-up aerospace company Orbital Sciences Corporation (OSC) proposed to build a mid-size upper stage for the shuttle, the Transfer Orbit Stage (TOS). TOS would fill the gap for orbits which the shuttle couldn't reach between the PAM-D2 and IUS class satellites. At that point OSC projected the sales of dozens of TOSes to commercial customers. It turned out that due to the Challenger accident and elimination of

low cost launch services only two TOS were sold - both to NASA. NASA had to find payloads for its TOS and selected Mars Observer and the Advanced Communications Technology Satellite (ACTS). Mars Observer was launched on a Titan III-TOS combination which used all of the TOS's capabilities. ACTS, due to its large antennae, had to be launched from the shuttle. The ACTS satellite was based on a standard communications satellite bus, the same one used for the PAM-D2 class RCA Satcom Ku series. Quite obviously TOS was overpowered as the ACTS perigee stage. The ACTS satellite, with its built-in apogee kick motor weighed 2,733 kgs. TOS's quoted geosynchronous transfer orbit capability, with a full propellant load is 6,090 kgs. - a difference of 3,357 kgs! As it turned out the TOS's solid propellant motor was off-loaded to fit the ACTS mission's requirements. Could we have built a satellite to fit in between the TOS and ACTS spacecraft similar to the original 'Falcon' Phase 3D design? There's no technical reason why we couldn't have had a payload on Discovery last September when it deployed the ACTS spacecraft.

Another similar case was the Italian IRIS upper stage. The Italian space agency, ASI, decided that there was a market for satellites in the 1/2 PAM D class. They signed an agreement with NASA and went ahead with the IRIS development. Much later they realized that they needed a payload to fly on IRIS. Since there were no satellites in that weight class ASI made a market "survey to look for potential customers. Since there was no launch vehicle at the time for that weight class satellite it isn't surprising that there weren't many payloads searching

for an IRIS-class launch vehicle. ASI investigated some possibilities, and eventually decided to build a duplicate of NASA's LAGEOS satellite. The very fact that ASI had to build its own payload for its planned upper stage's first mission should have indicated that they may have over estimated their potential market. As with the ACTS case LAGEOS used less than half of the IRIS's quoted capacity. If we 'piggy-backed' the IRIS/LAGEOS mission we could have had a satellite in a high circular orbit with a 52 degree inclination, or used that as a springboard to a more useful orbit for our purposes.

It's not likely that new upper stages will come along with so much excess capacity in the future, but we should keep our eyes open for every potential opportunity.

Another possibility is to piggyback on an existing satellite, similar to the Russian RS series. Russian RS 'satellites' are actually just amateur transponders which fly on Russian navigation satellites. The mother satellite provides power to the amateur payload and other housekeeping functions. The advantages are many - we only have to build our communications payload - what hams are most interested in. We don't have to build propellant tanks, propulsion systems, power subsystems, or all of the other components required to make a working spacecraft. On the other hand there are disadvantages to the piggyback route. We have to go where the primary satellite wants to go, we may have limited power available, our antenna farm may be limited depending on the primary spacecraft's requirements, and - perhaps most importantly - we have to go by their rules. Our payload has to be built to the primary customer's specifications, increasing our costs.

Nevertheless - here's two interesting possibilities for upcoming U.S. satellites where their ballast could have been our payload.

When NASA's Tracking Data and Relay Satellite (TDRS) system was designed it was supposed to be everything for everybody. Besides tracking the shuttle and other low orbiting satellites and providing relay functions TDRS was also supposed to include transponders for commercial communications in both C and K bands. Two things made this plan fall apart. Because NASA was offering extremely low costs for shuttle launches many communications satellites were being built on speculation - build and launch now while prices are low

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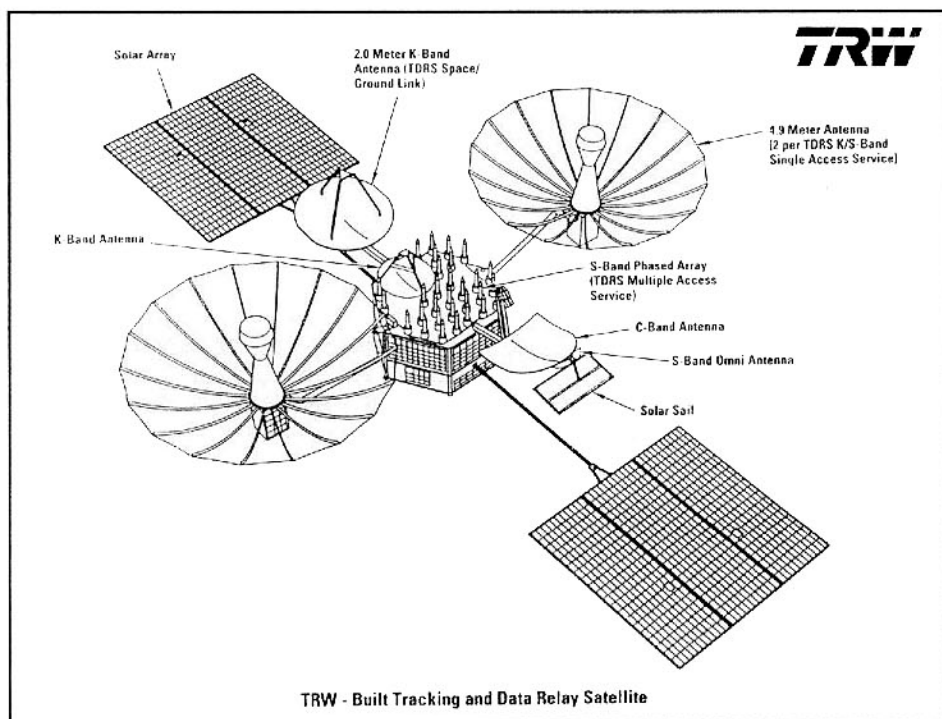


FIGURE 2 - TDRS Configuration

in the hopes of an expanding market in the future. In the mid 1980s there was a massive glut of excess capacity on commercial transponders - nobody really needed the extra TDRS capacity. In addition NASA had to include the provision that TDRS's commercial circuits could be preempted by 'national security requirements'. No commercial customer wanted to sign a lease with that requirement. It wasn't until 1991 that NASA was able to sell the commercial transponders on two of the operational TDRS to Columbia Communications. After the Challenger accident NASA received funding for a replacement TDRS and IUS upper stage. Knowing that there was no longer a requirement for commercial transponders the decision was made to leave them off the TDRS-G spacecraft. To keep things simple the existing design was retained with the commercial transponders replaced with ballast.

I discussed this situation with NASA Associate Administrator for Communications Charlie Force. He indicated that he would be quite willing to accept an AMSAT payload on TDRS-G, as long as it didn't interfere with TDRS's operation. There was a small amount of interest in the project, but all of our resources were dedicated to the Phase 3D program and nothing was done about the TDRS-AMSAT concept.

A similar situation exists with the Air Force's Milstar spacecraft. The first satellite includes a classified communications

payload. Due to the end of the Cold War, and Milstar's changing role from a strategic to tactical satellite there is no longer a requirement for that payload and it will not be included on future spacecraft. There will only be one additional Milstar 1 design spacecraft. It will include ballast in place of the payload. Future Milstar will include additional medium data rate transponders. Could we have included a set of amateur transponders? It would be a nice idea, but imagine a crisis situation in the future where Milstar is moved to give better coverage over the crisis zone. It's quite conceivable

that we could be put into a situation where we would not be permitted to publish or distribute the Keplerian elements for our own payload!

Regrettably the TDRS and Milstar opportunities for a geosynchronous amateur payload have been lost and future TDRS and Milstar will probably have revised designs which will eliminate the ballast requirement.

In any case we certainly should keep looking for future piggyback opportunities. As with the microsat series we can get redundancy and additional coverage through multiple spacecraft.

In 1992 the Superbird B1 spacecraft flew by itself on the Ariane 55 mission with an Ariane 42P launch vehicle because Arianespace couldn't find an additional spacecraft ready to go at the same time. Considering how long Arianespace has been launching spacecraft this is an excellent record. There was excess capacity on the mission and if we had a spacecraft ready-to-go we could have negotiated an extremely inexpensive launch rate. If we had planned ahead of time for an opportunity like this we would have had a year's advanced notice before launch to complete our 'standby' spacecraft. The concept of building a spacecraft to wait in a warehouse for potentially many years before a launch opportunity is available may not appeal to everybody, but the price is certainly right!

Another potential for launch services is incremental launch vehicle improvements. If an existing primary customer is already

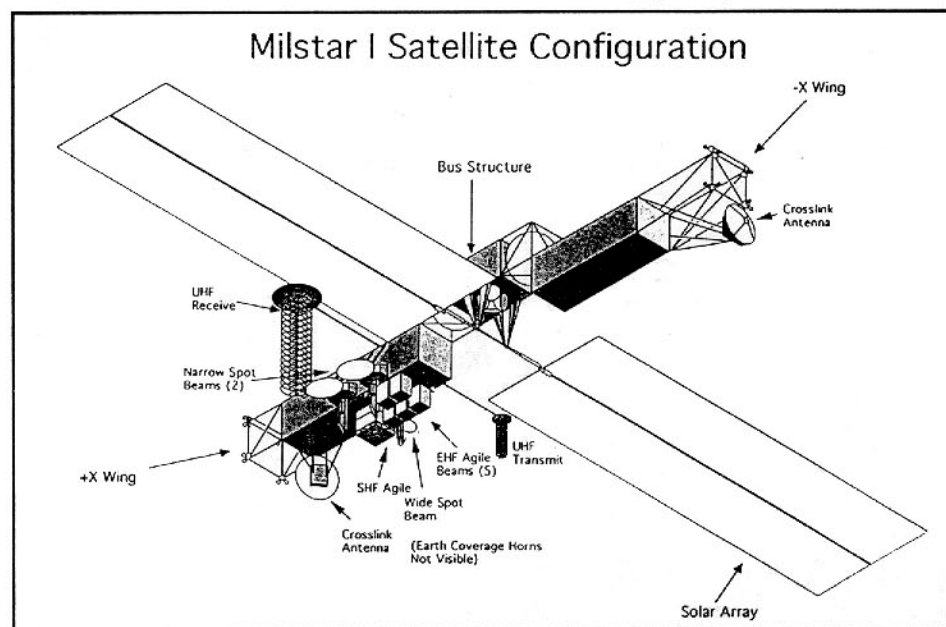


FIGURE 3 - Milstar 1 configuration

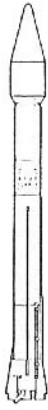
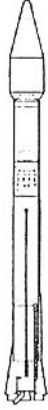
	ATLAS I	ATLAS II	ATLAS IIA	ATLAS IIAS
				
PAYLOAD SYSTEM WEIGHT TO GTO	2250 KG (4,950 LB)	2680 KG (5,900 LB)	2810 KG (6,200 LB)	3,490 KG (7,700 LB)

FIGURE 4 - Commercial Atlas Launch Family

launching a medium class launch vehicle we can offer to pay for part of the difference to upgrade to the next higher model. This is especially appealing for a customer who would prefer to purchase the larger model but has not decided whether or not it's worthwhile. For example, when Eutelsat chose to launch one of their satellites on a commercial General Dynamics Atlas they selected the Atlas I, the least powerful

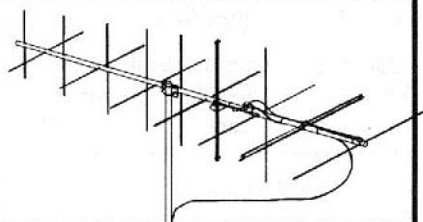
model. The contract included provisions for an optional upgrade to the Atlas II model which was the one which actually flew. Most future Atlases will be the Atlas IIA model which includes higher performance upper stage engines. We could offer to customers to pay for part of the upgrade to the Atlas IIAS model which adds four Castor IVA solid motors for additional performance. A call to Thiokol confirmed that four Castor IVA motors would cost about \$4 Million. While this amount of money would be difficult to raise by ourselves it's more than likely that we would split the difference with the primary launch vehicle cus-

tomers and contractors. Martin Marietta, which now owns the Atlas launch vehicle and what used to be General Dynamics Commercial Launch Services, has indicated that they would certainly be interested in developing the capability to fly piggyback payloads on their launch vehicles.

Several small payloads have flown as piggybacks on NASA and Air Force Delta second stages. In some cases the payload remains attached to the Delta's second stage and only operates for a couple of hours. In other cases lightsats have been ejected after the primary payload has completed its mission. NASA Marshall has tested the SEDS (Small Expendable Deployer System) tether on two Delta missions. In these cases diagnostic payloads have been deployed on a tether. There are plans to use the SEDS tether to deploy microsats into higher orbits, most notably SEDSAT from the University of Alabama. Currently there are plans to move the SEDS program from the Delta to the shuttle, which would result in more limited spacecraft lifetimes though.

While launch vehicles to geosynchronous transfer orbits and cases where the spacecraft has been optimized for a particular launch vehicle have little excess capacity most other launch vehicles will have some unused capacity. In some cases ballast is used or propellant is off-loaded. In other cases the launch vehicle will actually make a little 'side trip' on the way to orbit

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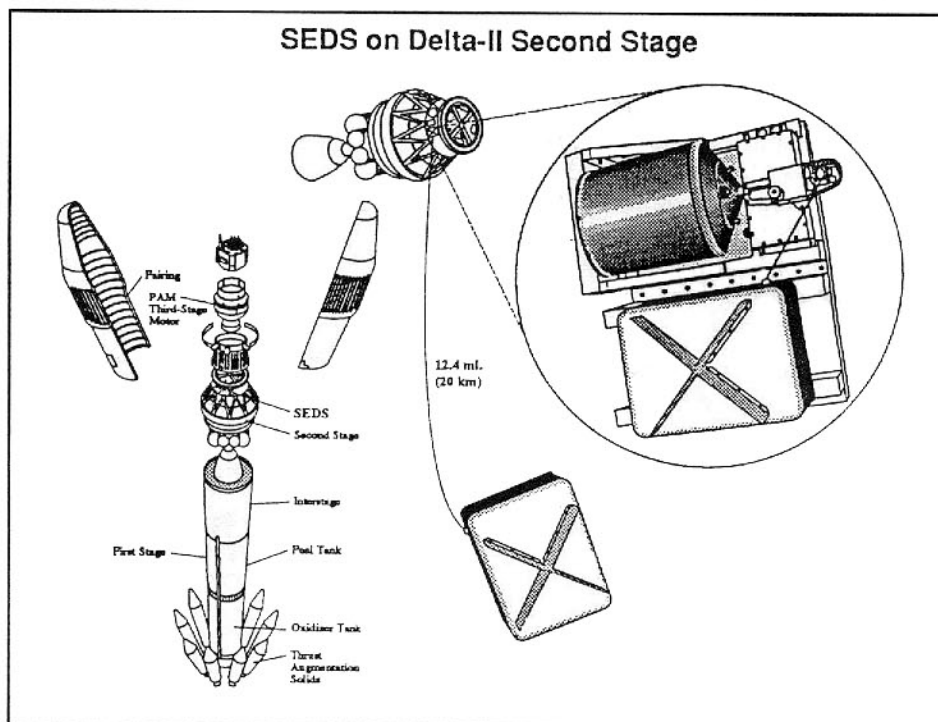


FIGURE 5 - SEDS on Delta-II Second Stage

to get rid of that excess velocity. Naturally that capability should be used.

Orbital Sciences is offering its Picolab, microsat-class satellites which can be flown on Pegasus launch vehicles with excess capacity. Currently their prices are too expensive for us to even consider (\$3M for the satellite and launch services), but OSC may be willing to offer space to us in many special cases. We could fly as standby payloads when other Picolab customers aren't ready to go, our payloads could include multi-purpose spacecraft like the Eyesat spacecraft, and there's always the possibility of special deals.

To date eight satellites including two classified spacecraft, have been ejected from Getaway Special canisters mounted within the shuttle's cargo bay. Before the Challenger accident it was a relatively inexpensive system. Since the new GAS policy was released optional services, like ejectable spacecraft, are now in a new category - Hitchhiker Junior. The pricing policy has not been released, but is almost certainly too expensive for us to consider. In addition GAS ejected satellites have very limited lifetimes, on the order of a year before

reentry. There always is the possibility to get out of the shuttle's orbit into a more useful orbit though. Jan King has proposed a system based on the electrolysis of water driving a hydrogen-oxygen thruster as an upper stage. Another possibility would be some kind of tether deployment system.

One method to get inexpensive launch services which we have always used is new, unproven launch vehicles. Established customers do not want to risk their spacecraft on new launch vehicle designs unless absolutely necessary. When a launch vehicle manufacturer doesn't have a proven track record they are often willing to offer launch services extremely inexpensively to get themselves established. Some potential launch vehicles include AeroAstro's PacASTRO, Lockheed's LLV, and AMROC's Aquila. Still, we should be aware of the additional risks associated with launch vehicles without proven track records. Most of us still have painful memories from the loss of Phase 3A on the second Ariane launch.

In addition to all of these possibilities we shouldn't forget launch vehicles from other countries. Japan, China, India, and -

of course, Russia all have strong launch vehicle programs which may offer additional launch opportunities.

From a strictly technical point of view, the best existing launch site in the world for Molniya (Phase 3D) orbits is Plestok, near Archangel in Russia at 62 degrees North. This site also has the political advantage of being within the Russian Republic.

One of the most unusual launch platforms is hand ejection from Mir's airlock. Some small spacecraft, including two Russian amateur satellites, have been shoved out of Mir's airlock by a space-suited cosmonaut. The primary disadvantage to this method is limited lifetime. Mir is in a relatively low orbit and any hand-ejected spacecraft will have extremely limited lifetimes.

Future launch vehicle opportunities will be more limited than they have been in the past. We will have to pay more for launches than we have had to pay before, and will have to get more creative in finding new opportunities to put amateur transponders into space.

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Advanced Electronic Applications, Inc. has a solution for satellite tracking and tuning—the ST-1 Satellite Tracker. The ST-1 offers satellite users hardware and software for automatic satellite tracking and transceiver tuning. The ST-1 connects to your PC computer, your computer compatible transceiver, and your rotors. The ST-1 uses one serial and one parallel port. Pass through connectors allow use of ports when the ST-1 is turned off.

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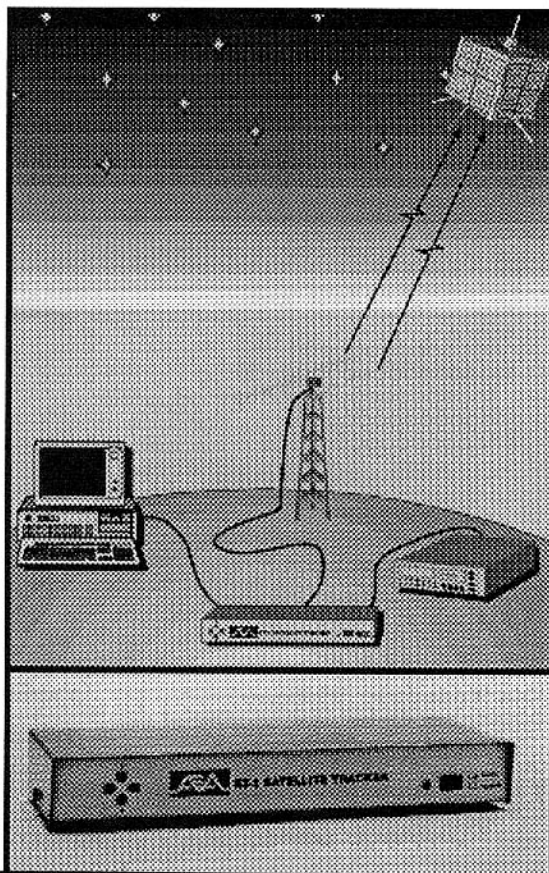
The ST-1 controls everything. If there is a file you want to retrieve from a satellite, type the file you want into your computer and the ST-1 does everything for you while you sleep, work—whatever! Using satellites couldn't be easier.

FEATURES

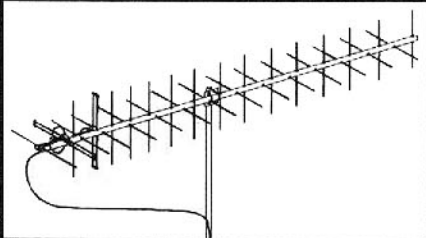
- Allows unattended operation on Packet satellites.
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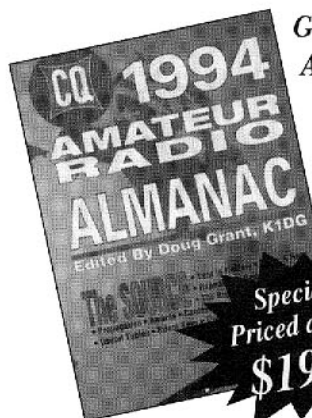
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By Ed Krome, KA9LNV

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The Four Seasons Of AO-13

By William Roth, N7RYW

For the last few months, OSCAR 13 has had a bad attitude. Most of us have heard the reasons why, that the sun angle is bad because of the orbit. You might have also heard that the orbit is changing and will lead to a serious case of burnout late next year. The details, however, are not very easy to understand so I will see what I can do to make the information useable. I will also cover an area of continual concern, and that

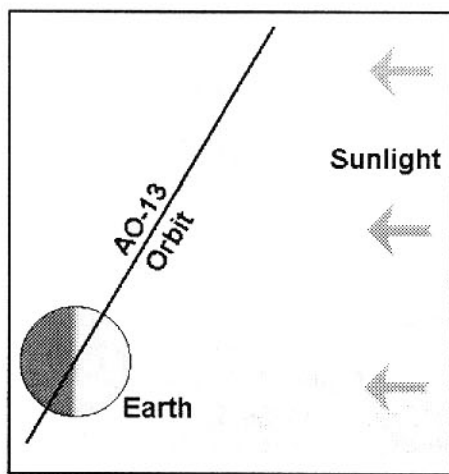


FIGURE 1

is transponder loading and mode schedules.

So, why is it that the satellite has these problems? Why do the command stations tell it to point off into the distance half the year? Why does the sun not shine on it the way it did before? Why am I asking you, when I am supposed to be the one providing the answers!?

The most helpful thing for me to gain a real understanding of the elliptical orbit was for me to stop using references to any points on the Earth. When I pictured the Earth as a featureless sphere, it all came much more into focus. So, I'll ask that you do just that, too. Picture a ball (the Earth) and nothing else. Then we will add the sunlight and AO-13s orbit to the picture. Figure 1 is how it looked a few years ago.

As you can see, the orbit is rather sideways to the sunlight. This makes it easy to get the solar panels lit, since they are on the sides, and which is why this type of orbit (high inclination) is used. As we have heard, there have been changes to this orbit. These changes will eventually mean that the satellite will get real warm at the end of next year. The changes to the orbit are much more than just getting a little closer to the atmo-

sphere as time goes by. The orbit from the same view would now look like that in Figure 2.

Now, that's quite a change! As you probably know, the best pointing angle for communications is 180/0, or at the center of the Earth at apogee. This is also straight along the centerline of the orbit. Unfortunately, this means that the sun is right behind the bird, where there are no solar panels to keep the batteries charged.

One more aspect to know about is the centerline of the orbit. It is stationary, not in relation to the Earth or sun but to the Galaxy! There is a slight amount of drift, but it is very small, and we don't need to account for it here. Since the Earth orbits the sun, the result is that the sun is aligned with the orbit centerline twice each year. Again, a picture is worth a lot of words -- see Figure 3.

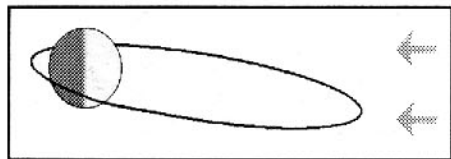


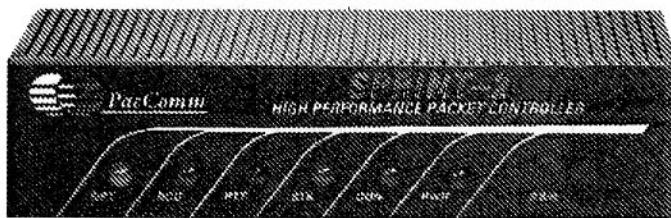
FIGURE 2



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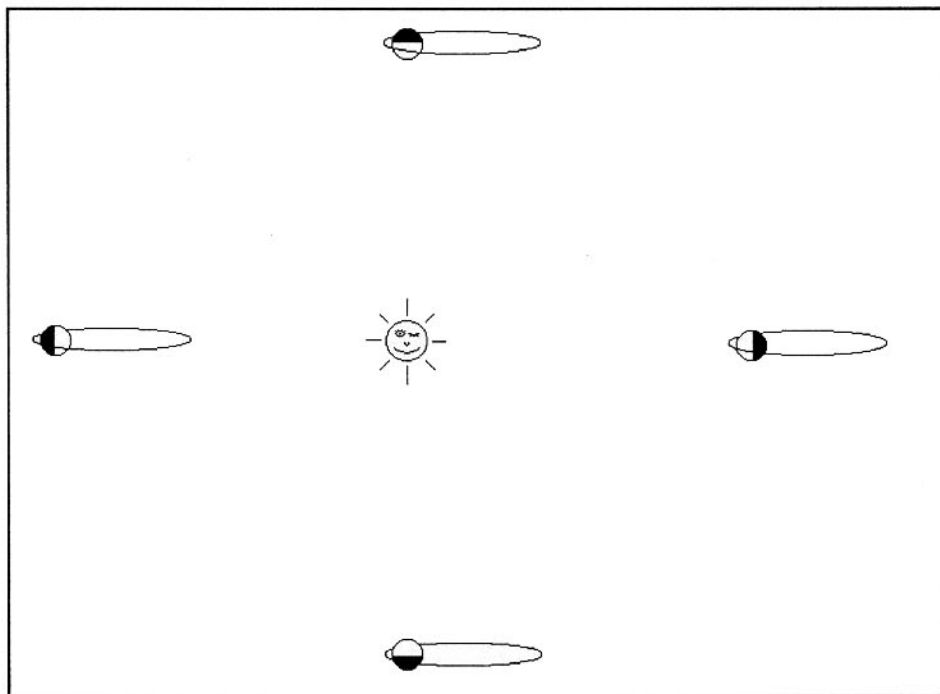


FIGURE 3

AO-13s solar panels are around the sides of the spacecraft. This means that the sun needs to be off to the side (or 90 degrees from the antenna pattern) for the batteries to be charged. With the attitude of 180/0, you can see that the sun angle is good at the top and bottom of Figure 3. At the left and right, however, the sun would be shining on the antennas and motor of the spacecraft, and no light would shine on the solar panels. So at these times the spacecraft is commanded to change its attitude to point the antennas away from the Earth at apogee. This has been to 230/0 lately, which allows for at least some communications.

Also note on the right that at the highest point of the orbit, the satellite would be in darkness from an Earth eclipse. At these times, the transponders are turned off to keep from discharging the batteries.

In Figure 4, the top depiction is if the satellite were to be at 180/0, with the sun shining on the motor. The bottom one is at 230/0, and there is some light on the panels, while the antennas are pointed somewhat away from the Earth at perigee. This is shown from above the orbital plane, not from the Equator.

The changing of the orbit continues. If you want, you can watch the Argument of Perigee parameter in the keps as time goes by, and you will see that the perigee of the orbit keeps moving north. It passed the Equator a few months ago. This means that our neighbors in the Southern Hemisphere

will be getting better and better pointing angles, while we in the North will be getting worse. It used to be that we could not communicate with Australia very well, but we now can. I have had talks with Graham, VK5AGR on mode S and I must say that I like the extra opportunities.

Speaking of mode S! The change in attitude to 180/0 will be coming up shortly, and I want to make an important point or three. I'll relate what happened the last time...

When AO-13s attitude was put back to 180/0 in late December, I jumped back on mode S, hoping to do some real talking with clear signals. I'm not into static, so I cherish the 2.4 GHz talks on mode S, especially the long, clear ones. With a 2 meter dish and automatic tracking, the quiet mode is really sweet. Or is it?

I tuned around, only to find multiple dead carriers sweeping the band with FAR too much power. One bloke was clearly holding the Dits on his paddle on the same frequency, trying to tune around with his receiver. The effect on the transponder was disastrous. It sounded like a machine gun, as the AGC clamped at every dit, and let go between. Everyone's signals were hammered, as there is only one AGC circuit that covers the entire uplink passband.

At first, I suspected that this CW signal was the result of someone not knowing the mode schedule. At times, we have heard about the importance of checking the mode schedule before transmitting to AO-13. It seems that not all have heard this request,

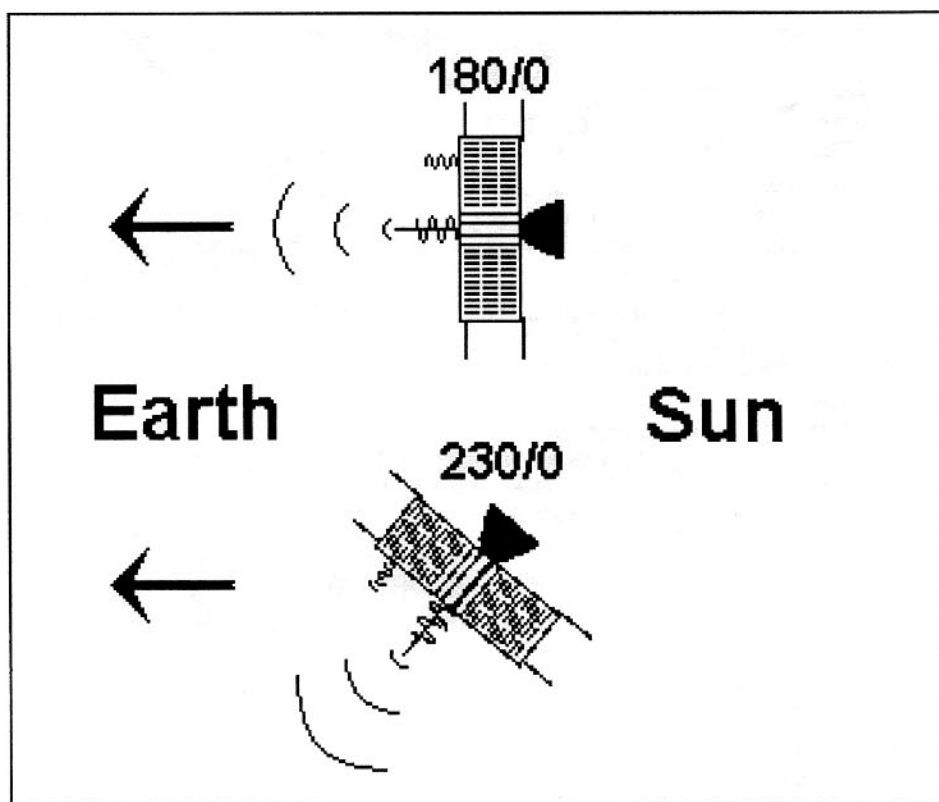


FIGURE 4

or don't understand it, or simply ignore it. We have also been in "Groan" mode while the birds' attitude (and therefore our own) is off in a bad direction. So, it seems that it is time for an explanation of just why we are asked to check the schedule.

"Why check the schedule? Why can't I just hold my key down and see if I can find my signal?" It would seem that you could do just that, as the uplinks for B and S are separate. There are a couple of good reasons why not. First, there is a problem with the bird. The mode B uplinks are mixed in with the mode S uplinks, then both are transmitted on 2.4 GHz. This is true even when mode B is off! The only way around this is for ALL users to look before they jump! Check the schedule! This is good common sense anyway. It is very impolite (to put it too nicely) to just start transmitting on top of someone and hope you can find the signal.

Checking the schedule is the first thing I do when I see AO-13 is up. The current schedule is available in many places. If you have Internet, both the amsat-bb mailing list and rec.radio.amateur.space have regular

postings, as well as the www.amsat.org web page. Don't have Internet yet? Packet bulletins are sent regularly. Don't have Packet? The AO-13 schedule is sent on AO-13 in CW, RTTY, and 400 bps psk on the beacons.

Speaking of beacons, there may be some confusion as to what mode is operating with what beacon. Some are hearing the 145.812 MHz beacon and assuming mode B is working. Not true! Due to a design factor, the 145 MHz beacon (instead of 2400 MHz) is operating while mode S is on. This is why just hearing the B beacon is not enough. It can be on while the B transponder is off. Again, check the schedule!

Not checking the mode schedule is not the only problem, however. For the entire time that AO-13 was at 180/0, a CW station was up hammering away at mode S. Many of us tried to ask them to reduce their power, but to no avail. I suspect that they were unable to hear a voice signal. So, it seems that there needs to be a bit of educating on just how the AGC works on mode S. This is from direct observation over a 3 month period.

The Automatic Gain Control circuit comes into play when a signal (any signal) received is excessive. If the receiver hears 6dB too much, it applies about 6dB of attenuation to the entire passband. So, I will apply these figures to an example of what happens...

A station is running about 25 watts to a good uplink antenna. His downlink, though, is poor, and they can't hear it very well. So, using the normal HF procedure when there's not enough signal, the amplifier is switched on and 100 watts is produced. This is 6dB more signal. Since 25 watts is the max before the transponder attenuates, there is 6dB too much uplink, and the signal is reduced by ~6dB at the satellite.

However, the received signal is perceptibly better! How can that be, you ask? Well, the attenuator works on everything that the transponder receives, including noise. The result is that the original signal strength is maintained on the downlink, but that there is 6dB less noise through the transponder. Hence, the signal is 6dB more out of the noise.

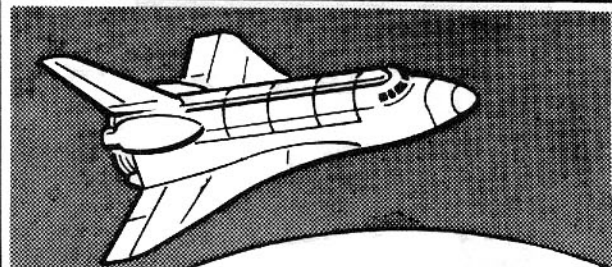
This sounds great, and it would be if there was only one user on the transponder. There are others who use it, however, so the result is one signal that sounds great, and every other one is 6dB down. A very poor situation indeed!

There is one more factor to consider for CW operators. If your power is set to 25 watts, you will probably activate the AGC on CW, but not on SSB. SSB rarely actually hits its peak power. If it does, it is for an extremely short period of time. Morse code, on the other hand, hits peak power on each and every element. So, even though the signal is just fine on SSB, it could very well be hurting on CW.

The result of too much CW power is quite dramatic. The downlink signals (except for the offender) are all chopped up. This can sound somewhat like spin modulation. If you have a good receive setup, you can actually hear the code in the noise over the entire bandpass as the attenuator applies and releases on each element! I never heard a spin calling CQ endlessly. I did a bit of experimenting, and 10 watts into my KLM antenna was PLENTY of uplink for Morse Code.

You can easily find out if you have too much uplink power. Turn on your mode S

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equipment a little earlier, and listen for the beacon. It is on for a few minutes before the transponder comes on. The reason it is on is so that you can get a look at what your downlink signal level should be AT THE MOST. Get your antennas pointed, and then note what the signal level is, and please don't exceed it when you transmit. The offending signals I have heard have been a full S-unit above the beacon and more.

All of this goes to show that there is absolutely no substitute for good receiving equipment. If you can't hear the beacon well, there's no reason to expect to hear other stations. Just using CW does not make up for a lack of receive. If you can't hear an SSB signal, you can't hear the desperate pleas to reduce your power! If you have trouble hearing yourself at 10 watts, instead of using more power please try working on your receive setup, and we can all use the "Silent Mode".

One big problem in getting tuned up is finding your own signal. Using the memories in my FT-736R has helped me to greatly reduce the tuning time (and therefore QRM) to get set up on OSCAR 13. With the memories set, you will be within a very few kilohertz of your signal to begin with on mode B. No more searching the whole band, looking for your signal and interfering with others! You can pull the needed frequencies from the list above and set up your memories for the modes you use.

It's true that you cannot use the VFO knob in memory mode on an FT-736R, but did you know that you can transfer the Memory contents to a VFO without changing what's in the memory? Some of us have done it using the VFO<>MEM and then the VFO>MEM keys, but you can do it also by pressing the F and then VFO keys while in Memory Recall. This is a real help, as you can store combinations of the frequencies in memories and go right to them. I just wish Yaesu would put this feature in the manual!

Once you have a frequency pair ready, be sure to tune around and see if there is anyone on the transponder before you transmit that carrier! If you don't hear anyone, double check the schedule and the date. It may have changed. If the transponder is on, try to find a spot where there are a few kHz of open space to prevent QRM while you are tuning up. Once you are ready to

find your own signal, make sure that you vary your TRANSMIT frequency. This is so that you are not sitting on top of someone's conversation with a steady carrier while you tune your receiver looking for it.

Now, this all may seem like a lot of work just to say "Hello" to someone on a satellite. At first, it is. But with a little practice, it is a LOT easier, certainly better than tuning the whole passband trying to find your own signal! With your help, mode S can again be a LOT of fun and mode B will be much improved as well.

For all you mode S stations, how many of you have tried mode BS? Not the content, the mode. With the mixing I mentioned earlier, you can talk to someone who is on mode B without all that VHF static and intermod! How? Transmit to them on the normal mode B frequency, but listen on mode S. You will hear both them and yourself as usual. This takes a very good understanding of the frequency relationships between the transponders. Hint: You'll need LSB on both VFOs, and the signals are non-inverting. I made up a cross reference for myself to keep it all straight. I based this on a 145.900 downlink, which is a good

reference. All of these frequencies are equivalents between the modes, and were tested with <100 Hz Doppler on 2400.750 mHz.

Mode B Tx	Mode S Tx
435.497.1	435.620.0
Mode B Rx	Mode S Rx
145.900.0	2400.745.7
	(144.745.7)

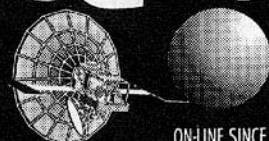
Your mileage may vary due to Doppler, individual radio tuning, and especially 2400 mHz conversion differences. Mine is the Down East Microwave unit, which I calibrated to within 100 Hz (warm) at the time of the test. The S uplink does not, as far as I can tell, get downlinked on B. Be sure to let your converter warm up for a while before trying this. Using this cross-mode, I was able to talk to a group of friends one night, and they couldn't even tell what I was up to. The S passband is narrower than the B, so there are limitations.

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1995 AMSAT Field Day Competition Announcement

by Andy MacAllister WA5ZIB

Field Day is once again just around the corner on June 24th and 25th, and we are proud to announce the 1995 AMSAT Field Day competition. Last year's effort was very successful. The AMSAT competition is to encourage the use of all amateur satellites, both analog and digital.

Here are the rules for the 1995 AMSAT Field Day competition.

1. ANALOG TRANSPONDERS

Each satellite transponder is considered a separate band. This means that AO-13 mode "S" is separate from AO-13 mode "B".

All phone QSO's and all CW QSO's on a given satellite transponder are considered separate bands. This means that AO-13 mode "S" CW is separate from AO-13 mode "S" phone.

Therefore, for reporting purposes, AO-13 has four possible "bands" including

mode "B" CW, mode "B" phone, mode "S" CW and mode "S" phone. On the reporting sheet under the "Satellite/mode" heading show the satellite name and transponder mode. Example: AO-13/B. Columns are provided for tabulation of CW and phone contacts. All packet/RTTY/ASCII/AMTOR QSO's through analog transponders are counted as CW QSO's.

Phone QSO's count for one point and CW QSO's count for two points. Cross-mode (CW-phone) contacts are not allowed.

The use of more than one transmitter at the same time on a single satellite transponder is prohibited. This means that two stations at the same Field Day site can operate through AO-13 at the same time, but only if one is operating mode "S" and the other mode "B". If two stations at a given site are set up for mode "B" operation, only one can be on AO-13 (CW or phone). The other station can be used for different hamsats (like AO-10) or other Field Day

activities.

2. DIGITAL TRANSPONDERS

For the pacsats (LO-19, KO-23, etc.) each satellite is considered a separate band.

Do not post "CQ" messages. Simply upload ONE greeting message to each satellite and download as many greeting messages as possible from each satellite. The "subject" of the uploaded file should be posted as "Field Day Greetings" addressed to "ALL". The purpose of this portion of the competition is to demonstrate digital satellite communications to other Field Day participants and observers.

The following uploads/downloads each count as a five point digital contact:

(a) Upload of a Satellite Field Day Greetings file (one per satellite).

(b) Download of Satellite Field Day Greetings files posted by other stations. Other non-Field Day files are not to be counted for the event.

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Digital Communications with Phase 3D

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by Harold E. Price, NK6K

The 400 kg Phase 3D satellite will have up to 250 watts output PEP, or about 60 watts continuous. Of that 60, the digital transponder (called RUDAK-U) will have about 20 watts allocated to it. The digital RF inputs and output come and go through an 10.7 MHz IF matrix, giving us access to a variety of uplink and downlink frequencies. The actual frequency bands are shown in Table 1.

P3D will be flying a plethora of DSP-based modems. While the Surrey Satellite Technology UoSATS were the first to fly DSP modems on amateur spacecraft, P3D will be flying several, eight modulators and eight demodulators. The modems can appear anywhere within the digital sub bands described in Table 1.

Most of the information below comes from the RUDAK-U project manager and lead hardware designer, Lyle Johnson, WA7GXD. The design is near final, but still subject to change. The basic configuration of the digital section is shown in figure one. There are two CPUs, a V53 and an 80386.

Each will have 16 MB of EDAC protected program and file storage space. Each processor has a connection to the payloads, via serial port, the one Mbit CAN-bus, or both. Each processor has its own set of "low" speed DSP-based modems (up to 56 kb or so). The processors share a single 256 kb modem.

The two main processors are reloadable from the ground or each other. The DSP modems and payloads are reloadable from the ground via the main processor's on-board storage. The processors/DSP modem complex has 18 programmable processors.

The 9600 baud modems are hardwired, and will be used for the initial loading and as backup to the DSP modems. They will be on fixed frequencies in the digital sub band. At least one of the frequencies will not be published, to provide a contention-free command and loading channel.

The DSP modulators and demodulators use the ADSP2171 CPU. Each modulator and demodulator chain has a separate processor, allowing the full power of the DSP chip to be used for a single half duplex link. This will allow high baud rates, up to 56 kb, or very heavily coded low baud rates. Each DSP has 10k bytes of internal, non-EDAC protected memory. The DSPs will perform an internal CRC on program memory every second and report back to the main processor, which will reboot the DSP on bad CRC or timeout.

A demodulator is fed from a high speed video ADC. Though each demodulator could use its own ADC, each is seeing the same IF and could share an ADC with one or more other demodulators. The decision, as always, is one of redundancy versus complexity and as not yet been made. Each demodulator uses its own HSP50016 Digital Down Converter (DDC) to convert the digitized 10.7 MHz IF to a frequency range more suitable for digital processing. [1] This also allows the uplink frequency to be anywhere in the passband, under software control. Likewise, the modulators use the AD7008 Direct Digital Synthesizer (DDS) to generate 10.7 MHz IF. This allows the modulators to also appear anywhere in the passband, under software control. The DDC and DDS allow the processor to specify a phase increment to an internally generated sine wave. The DDS also allows an amplitude to be specified. Since the DSP need

Table 1:
P3D Communications Links

UPLINKS

"H" 15M			21.200	(50KHz)	21.250	
"V" 2 M	145.800	Digital (40KHz)	145.840		Analog (150 KHz)	145.990
"U" 70 cm	435.300	Digital (250 KHz)	435.550		Analog (250 KHz)	435.800
"L" 23 cm (1)	1269.00	Digital (250 KHz)	1269.250		Analog (250 KHz)	1269.500
(2)	1268.075	(250 KHz)	1268.325		(250 KHz)	1268.575
"S" 13 cm (1)	2400.100	Digital (250 KHz)	2400.350		Analog (250 KHz)	2400.600
(2)	2446.200	(250 KHz)	2446.450		(250 KHz)	2446.700
"C" 6 cm	5668.350	Digital (200 KHz)	5668.550		Analog (250 KHz)	5668.800

DOWNLINKS

DOWNLINKS

"T" 10M	29.330 +/- 5 KHz (to be used for digitized voice Bulletins)				
"V" 2 M	-----Analog----- -----Digital-----				
	145.805	(150 KHz)	145.955	(35 KHz)	145.990
BCN (.450)			BCN (.850)		
"U" 1	-----Analog----- -----Digital-----				
70 cm	435.475	(250 KHz)	435.725	435.900	(300 KHz) 436.200
BCN (.200)			BCN (.600)		
"S" 1	-----Analog----- -----Digital-----				
13 cm	2400.225	(250 KHz)	2400.475	2400.650	(300 KHz) 2400.950
BCN (.000)			BCN (.400)		
"X" 1	-----Analog----- -----Digital-----				
3 cm	10451.025	(250 KHz)	10451.275	10451.450	(300 KHz) 10451.750
BCN (.000)			BCN (.400)		
"K" 1	-----Analog----- -----Digital-----				
1.5 cm	24048.025	(250 KHz)	24048.275	24048.450	(300 KHz) 24048.750

Note: Downlinks are inverted Uplinks. Mode B (today) will be "Config U/V" (Uplink/Downlink). Config UL/VSX is possible. Lack of 2M beacon is due to characteristics of matrix and limited bandwidth available. Studies continue.

Layout by K2IYQ, 1 Feb 95

not generate each point on the sine wave, the input and output frequencies can be much higher than the DSP chip alone could use.

The DDS and DDC can be used to allow each ADSP2171 to process more than one low bit rate signal at a time, giving us more than 16 uplinks, perhaps as many as 32 or 48 low bit rate uplinks. What could we do with such a thing? Why, that's the fun part, of course. Readers are invited to send in application ideas for all this horsepower. Before we get too carried away with thoughts of competing with Qualcomm and Orbcomm, let's review the link budget.

TANSTAAFL

The above is an acronym for "There ain't no such thing as a free lunch," a phrase I was first exposed to as a child in Robert Heinlein's "The Moon is a Harsh Mistress", and which I've encountered in real life ever since. The P3D orbit (43,000 km) has a few advantages over the Low Earth Orbit (800-1300 km) spacecraft digital users are used to. The spacecraft is much further away, meaning it moves more slowly and is visible for longer periods of time. It is also larger, meaning it can generate much more power, for louder downlinks.

Here is the TANSTAAFL part.

Since P3D is much farther away than a LEO satellite like KO-23, the path loss is also much greater. The increased path loss, in fact, just about wipes out the advantage of the higher power. For example, consider the case of a typical ground user of the 9600 UoSAT spacecraft, UO-22, KO-23, and KO-25. Most of them have what is called an "Oscar 10" class station, meaning tracking antennas with about 10 dB gain, and 10 to 100 watts of uplink power. For the LEO satellites, with about two watts on the downlink, this gives plenty of link margin.

For P3D, a similar amount of downlink power results in -0.1 dB of margin. We have a rule of thumb in the amateur satellite world that says the link margin on paper needs to be about 10 dB to give adequate performance at a typical user station. This 10 dB is usually labeled "implementation loss", and in my case, equates to the inability to correctly place an N-type connector on a piece of coax. Some link margins for P3D, and the data you need to compute your own, are in Table 2.

I want to be very clear on this. Much of the PR the P3D campaign sends out, and

I'm guilty as well, has been talking about 250 watt transmitters and much improved link performance for current users. The 250 watt figure and the improvements are from the point of view of current AO-10 and AO-13 voice users, not the current LEO 9600 baud data users. Still, the goal of the RUDAK-U module is to service the current digital satellite user community. To do this, we'll need to assign a substantial amount of our downlink power budget to a single 9600 baud downlink in the 70 cm band. This leaves us with the challenge of finding interesting applications for lower power, but presumably more heavily DSP-processed modulation schemes. We'll need matching DSP modems on the ground as well. In fact, the P3D project could well exceed the current amateur capacity to generate modem software. Volunteers?

There are other factors to keep in mind. RUDAK can transmit on more than one downlink band at a time. For example, we expect the spacecraft will often be in a mode

allowing both the 435MHz and the 2400 MHz downlink to be used. While we are servicing old-style users on 435 at 9600 baud, we could be handling gateways with big antennas and higher data rates at 2400 MHz. Back in the TANSTAAFL category, while each user will have a longer access time, several hours instead of ten minutes per pass; more users can see the satellite at the same time. Will this lead to more contention, or will the long access times lead to less contention, since users aren't all trying to download in the same ten minute interval.

All in all, we believe that we can provide access to P3D from current UoSAT 9600 baud FSK class stations. We may also provide access to Microsat 1200 baud PSK users. We can also, simultaneously on the same or other bands, provide access with new modulation schemes and new protocols. There will be fun for protocol developers and well as software modem designers on this mission.

Downlink, 9600 baud FSK

Frequency, MHz	436
Spacecraft	
Transmitter power, dBm	43
Line Losses, dB	0.7
Antenna Gain, dBic	13
Path	
Sat. Altitude, km	43800
Max. distance, km	49765
Polarization Loss, dB	0
Atmospheric Loss, dB	0.3
Ground Station	
Isotropic Signal at Ground, dBm	-134.1
Antenna Gain, dBic	13
Sky Temperature, K	50
Feedline Loss, dB	1
Receiver NF, dB	0.5
Bandwidth, kHz	15
Data Rate, symbols/sec	9600
Receiver Noise Temp., K	169.6
Receiver Noise Power, dBm	-134.5
User S/N, dB	13.4
Link Margin	9.9

The spacecraft antenna gain at 146 MHz is 10 dBic, at 2400 MHz it is 18 dBic.

Table 2a - P3D Downlink Margin. From WA7GXD.

Uplink, 9600 baud FSK

Frequency, MHz	146	1270
Ground Station		
Transmitter power, dBm	40	40
Line Losses, dB	1	1
Antenna Gain, dBic	12	24
Path		
Sat. Altitude, km	43800	43800
Max. distance, km	49765	49765
Polarization Loss, dB	0	0
Atmospheric Loss, dB	1	0.3
Spacecraft		
Isotropic Signal at Spacecraft, dBm	-119.6	-125.7
Antenna Gain, dBic	10	15
Sky Temperature, K	300	300
Feedline Loss, dB	0.7	0.7
Receiver NF, dB	1	1
Bandwidth, kHz	15	15
Data Rate, symbols/sec	9600	9600
Receiver Noise Temp., K	438.9	438.9
Receiver Noise Power, dBm	-130.4	-130.4
User S/N, dB	20.8	19.7
Link Margin	7.3	6.2

Table 2b - P3D Uplink Margin. The 1270 ground antenna gain is for a 1 meter dish. From WA7GXD.

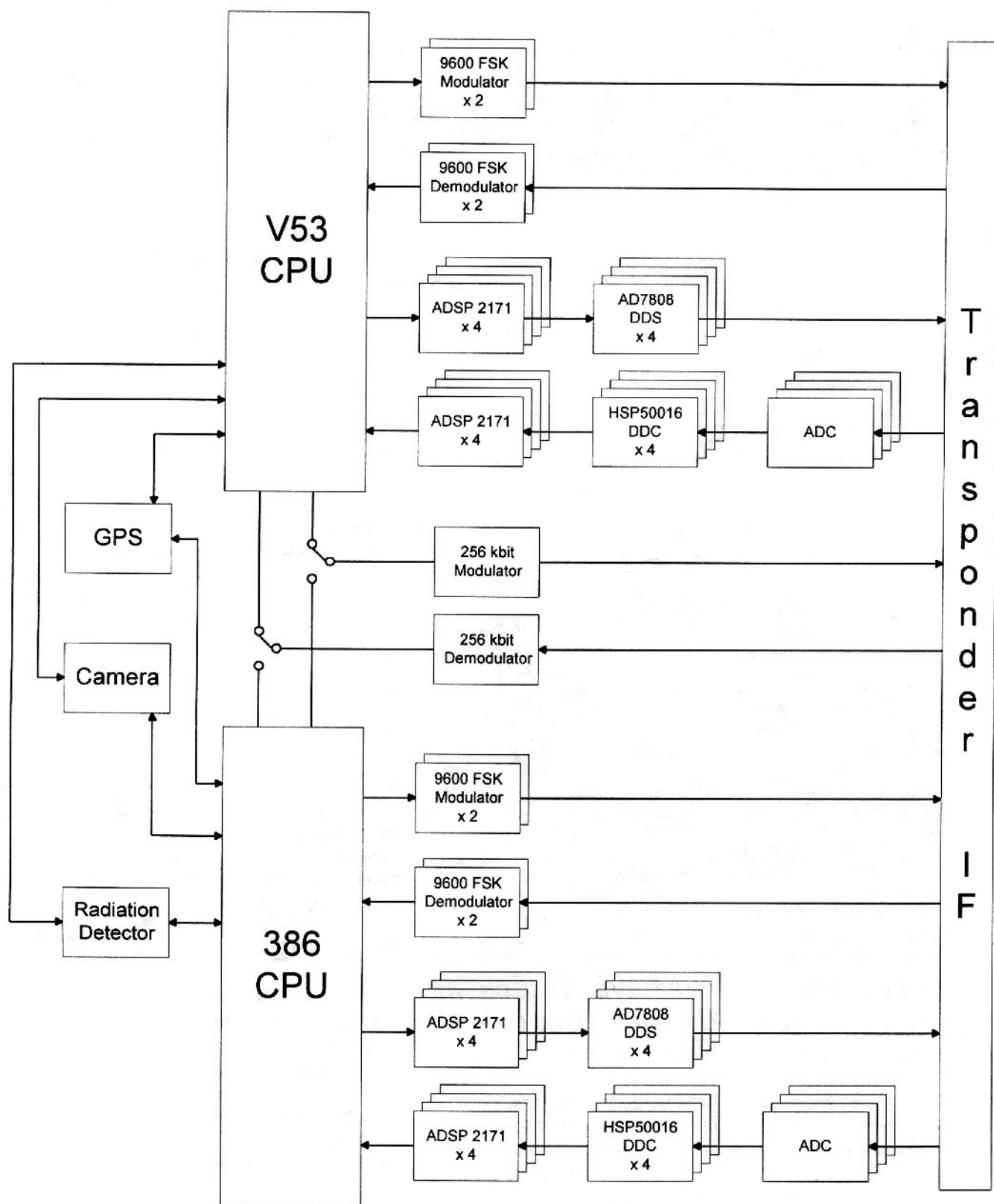


Figure 1: Block Diagram of the P3D Digital Electronics Package

Bob Myers Communications

PO Box 17108

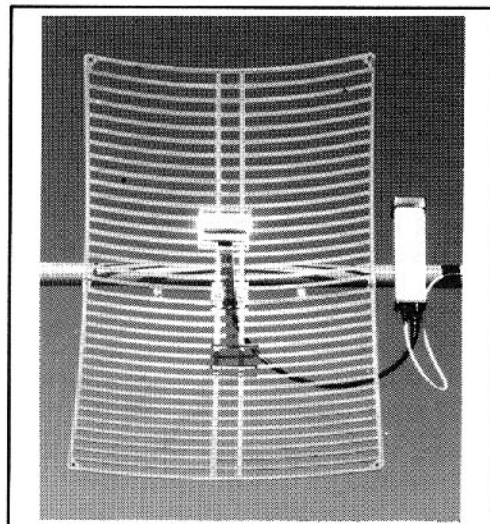
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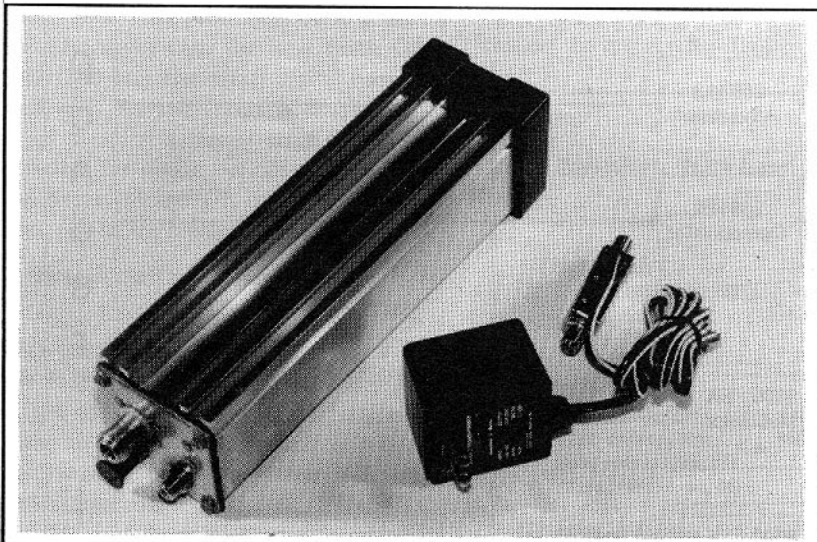
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